BIOLOGICAL AND ENVIRONMENTAL EFFECTS OF NUCLEAR WAR

HEARINGS

BEFORE THE

SPECIAL SUBCOMMITTEE ON RADIATION

OF THE

JOINT COMMITTEE ON ATOMIC ENERGY
CONGRESS OF THE UNITED STATES
EIGHTY-SIXTH CONGRESS
FIRST SESSION

ON

BIOLOGICAL AND ENVIRONMENTAL EFFECTS
OF NUCLEAR WAR

JUNE 22, 23, 24, 25, AND 26, 1959

Printed for the use of the Joint Committee on Atomic Energy of the subcommittee by Lt. Gen. James M. Gavin, U.S. Army, retired, former Deputy Chief of Staff for Research and Development.

> DEAR MR. HOLIFIELD: I have examined the theoretical nuclear attack pattern that is to be considered by your committee in the hearings beginning June 22, 1959. I consider your assumptions to be entirely realistic and well within the capabilities of a potential aggressor.
>
> JAMES M. GAVIN,
> *Lieutenant General (Retired).*

Are there any questions of the witness?

If not, you are excused, sir.

Mr. QUINDLEN. Thank you, sir.

Representative HOLIFIELD. Our next witness will be Dr. Frank Shelton, Technical Director, Defense Atomic Support Agency of the Department of Defense. Dr. Shelton will give a presentation of the effects of the different-sized weapons used.

STATEMENT OF DR. FRANK SHELTON,[1] TECHNICAL DIRECTOR, DEFENSE ATOMIC SUPPORT AGENCY, DEPARTMENT OF DEFENSE

Dr. SHELTON. Mr. Chairman, it is a pleasure to appear before the committee. I have a few figures that we will have to put on the easel, but I will begin because they are used partially down in the text.

The effect of a nuclear war is the sum of the effects of the weapons employed against the individual targets. The individual weapon's effects thus form the building blocks for the sum of the effects. It is generally true that the effects of blast, thermal radiation, and prompt nuclear radiation (emitted directly from the exploding bomb) will not overlap the same areas with important effects unless two or more bombs are detonated rather close together on a single target. Local fallout from surface bursts is about the only weapon effect that can be expected to have overlapping effects from one bomb to another and this is especially true in the downwind directions.

Thus, the total damage to the country from blast, thermal radiation, and prompt nuclear radiation is essentially the sum of the individual effects on the individual targets.

In the case of fallout one often has to add the effects of one bomb on another in their common fallout areas. Finally, worldwide fallout is the sum of each of the individual weapons contribution.

In summarizing the various effects, I would like to draw into perspective, in some small measure, the relatively large areas and are also likely to be involved by the other effects. As an example, the lethal fallout area giving about 700 rem in 48 hours——

Representative HOLIFIELD. Will you please explain rem?

Dr. SHELTON. Can I hold that? It is in the text, if you will allow me to wait until we get to that point.

Representative HOLIFIELD. All right.

Dr. SHELTON. An accumulation of about 700 rem in 48 hours for an unshielded person can be expected to occur over about 1,500 square

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[1] Technical director of the Defense Atomic Support Agency. He has been active in the atomice energy field since 1952. During the spring of 1955, he served as technical adviser to the military effects test group at Operation Teapot, and in 1953 participated in Upshot-Knothole. Dr. Shelton was born in 1924. He received his bachelor of science, master's and doctor of philosophy degrees, all in physics, from the California Institute of Technology. Prior to joining the Defense Atomic Support Agency, Dr. Shelton was with the Sandia Corp. in the weapons-effects field.

miles from a 10 megaton surface burst (50 percent fission); that is, an area that could be about 100 miles long and about 17 miles at the maximum width.

Few people appreciate the fact that, for the same bomb, second degree burns on the exposed face and hands and the ignition of fine kindling fuels can encompass an area of about 25 miles radius or about 2,000 square miles in the immediate vicinity and perhaps dense population of the target area. That is, this thermally affected area could be substantially larger than that of the lethal fallout area. And, if there is some shielding of personnel in the downwind fallout areas, the thermal effects area would certainly be the larger of the two.

Fallout and its potentially lethal areas are imporant, but so are the areas of the other effects; the pendulum of interest has swung to fallout and there is some tendency to overlook the very important other effects. Your expert witnesses in blast, thermal radiation, and prompt nuclear radiation also have an important part of the story. The results produced in Japan by the two nominal yield bombs were from only blast, thermal radiation and prompt nuclear radiation. There was no local fallout involved in the nearly 400,000 casualties in the tale of those two cities.

In discussing the effects of a large yield detonation it seems pertinent to:

I. Describe what happens when a nuclear detonation occurs; that is, how the blast, radiant heat, prompt nuclear radiation, and fallout are produced.

II. Next, I would like to describe very briefly the main differences in an airburst and a surface burst. I realize that the hypothetical attack assumed for these hearings utilizes surface bursts; however, a few words about airbursts does not appear out of place.

III. Finally, I would like a summarize the various weapons effects by relating the distances at which certain effects can be expected to produce a given level of damage to man or structures.

I. DESCRIPTION OF A NUCLEAR EXPLOSION

At the moment of detonation, a tremendous amount of energy is released in an extremely short time and small space. This rapid release of energy heats the bomb material and surrounding air to temperatures of several hundred thousand degrees, forming a luminous sphere of hot gases called the "fireball." The expansion of the air heated by the nuclear detonation causes the formation of a shock wave. At rather close distances to the burst, the shock wave is extremely strong and shocks the air to conditions such that it is radiant—that is, glows—and the fireball continues to grow in size. About 35 percent of the total energy of the explosion is given off as radiant thermal energy (see fig. 1) or heat, in essentially the same way that the sun radiates heat, although in the case of a bomb it is delivered very rapidly.

overpressure produces a crushing effect on the structure as it engulfs it. Since the blast wave is also a mass of air in motion at very high velocity, it exerts a dynamic force on the structure, tending to translate it in much the same manner as a hurricane wind. Such structures as multistory brick apartment houses are quite vulnerable to the blast wave. (See fig. 4.) All such structures would be destroyed, collapsed, within a radius of 7 miles from ground zero for a 10-MT weapon; that is, one having a total energy equivalent of 10 million tons of TNT.

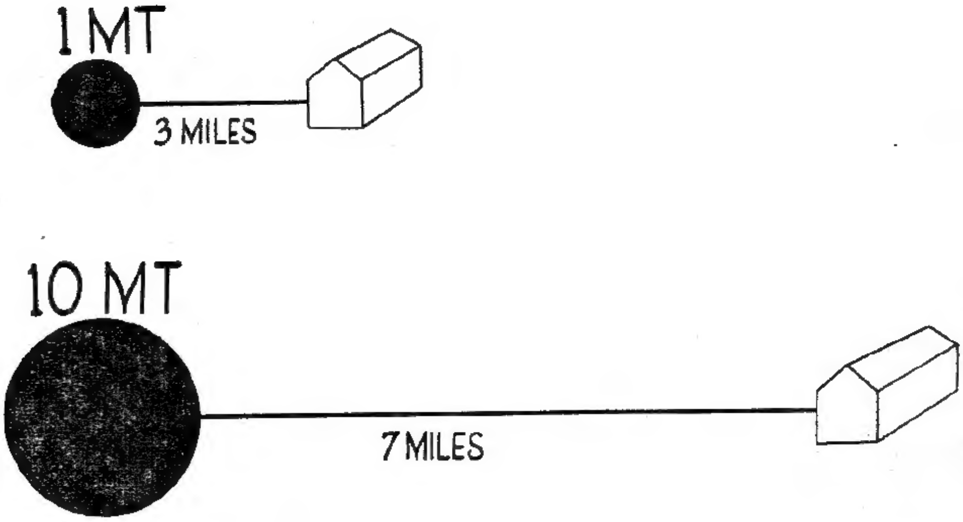
If we decrease the yield by a factor of 10, we have a 1-megaton weapon. For this yield, all such structures within a radius of over 3 miles from ground zero would be destroyed for a surface burst. Thus, a factor of 10 in yield will change the radius of blast damage by a factor of little more than 2.

Senator HICKENLOOPER. Just a moment, Mr. Chairman.

Representative HOLIFIELD. Senator Hickenlooper.

Senator HICKENLOOPER. I am having a little trouble here with the verbiage. You say if we decreased the yield by a factor of 10, we have a 1-megaton weapon. Then this sentence——

FIGURE 4



DESTRUCTION OF BRICK APARTMENT HOUSES

Dr. SHELTON. It refers to the previous sentence. We decrease the 10 megatons to 1 megaton.

Senator HICKENLOOPER. I understand you decrease the 10 to 1, but then this sentence.

> **For this yield, all such structures within a radius of over 3 miles from ground zero would be destroyed for a surface burst.**

As I take it that statement says everything over 3 miles beyond the center of the surface burst would be destroyed whether it was a hundred miles away or 200 miles away.

Dr. SHELTON. I can understand the problem there.

Senator HICKENLOOPER. We are dealing with a very technical and with a very, if I may use the word, frightening subject here, and I am concerned with the literal statements that are made.

(The information referred to follows:)

THERMAL IGNITION OF FRAMEHOUSES

There is some uncertainty as to whether or not persistent ignition can occur to well-painted good wood, such as the type of siding that is used on framehouses, under the conditions of a nuclear explosion. The following quotations are taken from "The Effects of Nuclear Weapons," and the referenced paragraph numbers are given:

7.62 "Wood is charred by exposure to thermal radiation, the depth of the char being closely proportional to the energy received. For sufficiently large amounts of energy, wood in some massive forms may exhibit transient flaming, but persistent ignition is improbable under the conditions of a nuclear explosion. However, the transitory flame may ignite adjacent combustible material which is not directly exposed to the radiation. * * *"

7.93 "From the evidence of charred wood found at both Hiroshima and Nagasaki, it was originally concluded that such wood had actually been ignited by thermal radiation and that the flames were subsequently extinguished by the blast. But it now seems more probable that, apart from some exceptional instances, such as that just described, there was no actual ignition of the wood. The absorption of the thermal radiation caused charring in sound wood but the temperatures were generally not high enough for ignition to occur. Rotted and checked wood and excelsior, however, have been known to burn completely, and the flame is not greatly affected by the blast wave."

7.82 "The fact that accumulations of ignitable trash close to a wooden structure represent a real fire hazard was demonstrated at the nuclear tests carried out in Nevada in 1953. In these tests, three miniature wooden houses, each having a yard enclosed with a wooden fence, were exposed to 12 calories per square centimeter of thermal radiation. One house, at the left, had weathered siding showing considerable decay, but the yard was free from trash. The next house also had a clean yard; and, further, the exterior siding was well maintained and painted. In the third house, at the right, the siding, which was poorly maintained, was weathered, and the yard was littered with trash."

7.38 "The state of the three houses after the explosion was as follows: The third house, at the right, soon burst into flame and was burned to the ground. The first house, on the left, did ignite but it did not burst into flame for 15 minutes. The well-maintained house in the center with the clean yard suffered scorching only. * * *"

Thermal effects comparable to those existing at these three houses would occur at 13 miles from a 10-megaton burst and at 6 miles from a 1-megaton burst.

Dr. SHELTON. Thus not only may your house be blown down, but it may be on fire due to the ignition of curtains or inflammable materials outside the house. There is a chance of a very large general fire throughout the area, a conflagration or fire storm. A fire storm existed at Hiroshima and lasted about 6 hours.

Representative HOLIFIELD. Will you explain for the record what a fire storm is?

Dr. SHELTON. In the case of Hiroshima, the fire storm was a general burning in the area of the target with air sweeping in, feeding the fire from all sides, and the heat rising up, a great smoke pall moving upward and out of the general area, so that there was a mass circulation of air. In other words, new fresh air was coming in to feed the fire. It burned for about 6 hours. At the edge of the fire storm there were winds like 30 and 40 miles an hour, and those generally subsided and became rather small and variable at the end of 6 hours.

The reason I mention the fire situation is that a fire that burns for times like 6 hours, raging in an area, even shelters there would have to direction should start about a half hour after the burst. In other words, you have about a half hour, but I don't know what you are going to do with it. You have a half hour if you want to use it before the fallout starts. 8 miles downwind from 10 megaton G.B.

Chairman Anderson. I am going to get under a shower. Somebody else can do what he wants.

Dr. Shelton. All right. The fallout will start and it won't be very intense at a half hour, and it will build up to a peak and it will be about 3,000 roentgens per hour or more at the end of the hour, if you are about 10 miles downwind. It is going to peak and be about 3,000 roentgens per hour outside on the level ground. You could not stand more than about 15 minutes of that radiation until you will probably be incapacitated, deathly sick, and terminate in death.

Chairman Anderson. Thank you.

3. Worldwide fallout

Dr. Shelton. Moving on from the local fallout it is certainly pertinent to discuss the worldwide fallout in this particular situation. I would like to say a few words about the worldwide fallout. If you remember, the large particles of radioactive debris were deposited locally, and the small minute particles from the explosion that enter the stratosphere spread more or less uniformly around the earth at a given latitude and fall to earth very slowly. As I said before, about 50 percent per year will come down to the ground. Here are those numbers that we have been discussing and let me say them once again. Here we have material away up in the stratosphere. What is going to happen to it? In 7 hours its intensity is down to one-tenth of the activity that we had at 1 hour. After 2 days it is down by a factor of a hundred. Two weeks it is down by a thousand. Three months it is down by 1 over 10,000. From this it is pretty apparent that the worldwide fallout that is coming down at a rate of about one-half per year, only contains those elements that are long lived like strontium 90, cesium 137, and carbon 14. They are the only ones that are left with any appreciable activity. To say what is happening in worldwide fallout for our hypothetical war situation, let me revert back to what we now know.

We expect 5 to 10 micromicrocuries of strontium 90 per gram of calcium to be the ultimate average value in the bone of man for the north temperate latitudes as a result of testing 90 megatons of fission yield. We know the effects for 90 megatons. Let us say what we are going to get for a thousand megatons. You get about 10 times as much. So you get 50 to 100 micromicrocuries per gram of bone calcium. I think in our war assumptions we have 2,000 megatons of fission products. So one would expect to get something like 200 micromicrocuries, which is a little larger than the maximum permissible concentration standard for the population as a whole, but which is a number, I think, that we recognize to be rather conservative. Similarly, let us talk about the genetic dose for a moment.

In the Northern Hemisphere the genetic dose from past testing has been about 0.05 rem over a 30-year genetic time period. So in the war we would expect about 0.5 rem per thousand megatons of fission yield in the weapons. We have 2,000 in our assumed case. So we would expect about one rem genetic dose. This is less than the person. The degree of incapacitation depends on the parts of the body exposed and the amount of energy received. For example, second degree burns of the hands are those which cause blistering, and are most painful, and will pretty effectively prevent work by that individual, and second degree burns of the eye area will certainly make one rather ineffective. For 1-megaton surface bursts, a person exposed within 9 miles of ground zero and with no shielding can be expected to receive second degree burns on any bare skin exposed directly to the bursts. For a 10-megaton weapon this range would be not quite three times as large in distance, about 25 miles away from a 10-megaton bomb. A person with exposed skin could expect to receive blistering, and second degree burns.

Representative HOSMER. In relation to protection against that, the areas that were clothed, would they receive any substantial damage?

Dr. SHELTON. The clothing area at this distance should minimize the burn to a blistering or sunburn type and not a blistering burn. Under clothing at these distances, the skin would have some protection and it would be like a sunburn, but not blistering. At closer distances, you can get second degree burns under clothing.

As another example, a person standing out in the open at 25 miles from a 10-megaton burst will receive blisters an all exposed skin. These second degree burns are the most difficult type to treat clinically. I am sure you will have an expert witness to cover this quite thoroughly.

Representative HOSMER. The protection factor on this type of thing is minimal.

Dr. SHELTON. Yes. All you need is something opaque between you and the bomb, any type of material, and the thermal hazard goes away down.

Representative HOLIFIELD. Dr. Shelton, I note there has been no discussion of the immediate neutrons.

Dr. SHELTON. They were included and integrated into the dose received from the prompt radiation. That last chart still on the floor showing the initial radiation resulting in probable death, has prompt gamma and prompt neutron added together into that dose. It does not matter what does it, if it kills you, and its effect on the tissue are very much the same.

5. Blast

Blast overpressure is itself not a very significant casualty agent. About 100 p.s.i. is required to have a significant effect of ruptured eardrums, for instance, and nuclear radiation, thermal radiation and fallout will almost certainly produce casualties where 100 p.s.i. can reach a man. However, the secondary effects and injuries caused by crumbling buildings, flying debris and translation of man himself are certainly very significant. Extensive blast injury can be expected at distances at which brick apartment houses collapse, and those distances were 7 miles from ground zero for a 10-megaton burst, and a little over 3 miles for a 1-megaton burst.

I believe you have a blast biology witness, Dr. White, in the later days, and I am sure he will tell you about the hazards of flying debris and in particular the hazard of flying glass. I would expect extensive window damage at 25 miles from a 1-megaton burst, and it would be an extreme hazard out to about 7 miles. Don't stand behind windows in an attack. First you will get burned and then you will have fine glass splinters driven into you very deeply within distances like 7 miles from a 1-megaton burst.

Representative **Holifield.** Every schoolroom in the United States has tremendous expanses of glass.

Dr. **Shelton.** Yes, sir.

Representative **Holifield.** I think this is a very important point you are bringing up, and I am sure it will be gone into in more detail when the blast witness appears before us.

Dr. **Shelton.** Yes. Glass in any disaster like the Texas City disaster is one of the primary materials found in the normal home which can result in blinding and all other types of effects due to the flying small splinters of glass.

My long acquaintance and friend, Dr. White, will fully expound on the hazard of debris, and particularly flying glass.

IV. SUMMARY OF EFFECTS FOR NUCLEAR WEAPONS FOR 1 AND 10 MEGATONS

To summarize the effects of nuclear weapons, they are blast, which is primarily a damaging agent to inanimate objects such as buildings, and it does produce flying debris which is a hazard to man.

The cratering effect results in the destruction of even deep underground structures. Thermal radiation damages both humans and combustible structures and materials. Nuclear radiation, including both the initial and the local residual fallout are primarily hazards to man and animals and can deny man the use of inaminate objects. For reference, I have included in table 1 the effects that I have been discussing for the last hour or so.

Table I.—*Summary of effects of the assumed nuclear weapons 1 to 10 megatons*

	1 megaton	10 megatons
A. Inanimate objects:		
1. Crater (dry soil)	Radius, 650 feet Depth, 140 feet	Radius, 1,250 feet. Depth, 240 feet.
2. Brick apartment houses collapse	Radius, 3 miles	Radius, 7 miles.
3. Ignition of light kindling materials	Radius, 9 miles	Radius, 25 miles.
B. Man:		
1. Blast injury (flying debris)	Radius, 3 miles Area, 28 square miles	Radius, 7 miles. Area, 150 square miles.
2. 2d degree burns on bare skin	Radius, 9 miles Area, 250 square miles	Radius, 25 miles. Area, 2,000 square miles.
3. Initial nuclear radiation (700 r.e.m.).	Radius, 1.5 miles Area, 7 square miles	Radius, 2 miles. Area, 12.5 square miles.
4. Fallout, 15-knot winds (450 r.e.m. in 48 hours, no shielding).	40 miles downwind, 5 miles crosswind. Area, 200 square miles	150 miles downwind, 25 miles crosswind. Area, 2,500 square miles.

Moving to man, let us just repeat again, blast injury, due to flying debris, occurs out to about 3 miles for a megaton weapon, and about 7 miles for a 10-megaton weapon. The areas there are about 28 square miles and 150 respectively. The burn area is a very large area, as you see, for a 10-megaton burst, about 2,000 square miles on clear days, or when the bomb thermal is easily seen. Fallout; in this case

450 rem in 48 hours, and no shielding, occurs in an area of about 2,500-square miles for a 10-megaton weapon.

Running down the columns, you notice that 10 megatons is 10 times the energy release of 1 megaton. But notice that the effects only reach out sometimes a factor of two, sometimes a factor of three, seldom ever a factor of four for the larger yield burst. A 10-megaton yield does not reach out to 10 times the distance. The distances are rather slow functions of yield, usually a factor of two, sometimes a factor of three. This is the variation in distance of a given effect from 1 to 10 megatons.

I did not feel that in the testimony I should cover two, three, and eight megatons. They can be interpolated in between the distances given and the uncertainties of effects are probably larger than warranted by exact mathematics for the other yields.

Representative HOLIFIELD. It occurs to me, Dr. Shelton, in the responses to Mr. Hosmer's questions, and other questions from members that you might want to prepare a statement in regard to this rate dose. You might include in that the factors of difference between, let us say, 10, 100-kiloton weapons, and 1 megaton weapon and such other pertinent information as you think would clear up and remaining doubts. We realize that we cannot cover the whole field, but we will try to do the best we can.

Dr. SHELTON. I will certainly do that, sir. (See table I, p. 41.)

Representative HOLIFIELD. Are there any questions of Dr. Shelton? If not, there is one question I would like to ask you, Doctor. Is it not true that if human beings are in the blast area, it is not only the external pressure upon the human individual's body which is dangerous, but also the human being himself becomes a flying missile, and is propelled through the air until he does strike an inanimate structure?

Dr. SHELTON. That is precisely right, sir. The body is able to withstand overpressures quite well. It is the flying debris, the translation of the man himself in the hurricane-like winds that accompany the bomb. It is this sort of thing that always accompanies the blast and produces the blast casualties.

Representative HOLIFIELD. Did you have anything else to add?

Dr. SHELTON. No, sir.

Representative HOLIFIELD. Thank you very much, Dr. Shelton. It might be well for the record to show that Dr. Shelton is Technical Director of the Defense Atomic Support Agency. He has been active in the atomic energy field since 1952. During the spring of 1955 he served as technical adviser to the military effects test group at Operation Teapot, and in 1953 participated in Upshot-Knothole. He has also participated in Operation Redwing in 1956, Operation Plumbbob in 1957, and Operation Hardtack in 1958. Dr. Shelton was born in 1924. He received his bachelor of science, master's, and doctor of philosophy, all in physics from the California Institute of Technology, and prior to joining the Defense Atomic Support Agency (formerly the Armed Forces Special Weapons Project), Dr. Shelton was with the Sandia Corp. in the weapons effects field.

We will hear from Dr. Machta again on a paper later on in this series of hearings.

Our next witness is Dr. Terry Triffet, from the U.S. Naval Radiological Defense Laboratory.

I may say for the benefit of the record that the U.S. Naval Radiological Defense Laboratory, which is located at Hunters Point, Calif., is an organization of some 600 scientists and other professional personnel that have been busy working on the problems of weapons effects with particular emphasis in the field of radiation, both on human beings, animals, and different types of physical materials, such as building materials and textiles, and all other types of materials. It is probably the center of our greatest depository for radiological laboratory information.

The managers of the laboratory have chosen Dr. Triffet to give us this part of the presentation. Dr. Triffet, you may proceed.

STATEMENT OF DR. TERRY TRIFFET,[1] U.S. NAVAL RADIOLOGICAL DEFENSE LABORATORY, HUNTERS POINT, CALIF.

Dr. Triffet. Mr. Chairman, gentlemen of the committee, I have prepared a formal statement which I would like to submit for the record.

Representative Holifield. It will be received.

(The statement referred to follows:)

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[1] Profession: Research engineer. Date and place of birth: June 10, 1922, Enid, Okla. Parents: R. B. Triffet, Enid, Okla. Married: Millicent McMaster, May 26, 1946. Children: Patricia A. Triffet. Education: B.A. (with honors) Human., University of Oklahoma, 1945; B.S. (with special honors) engineering, University of Colorado, 1948; M.S., engineering, University of Colorado, 1950; Ph. D., engineering, Stanford University, 1957. Professional and honorary societies: APS, ASCE, Society of Rheology, AAAS, Sigma Xi, Phi Beta Kappa, Tau Beta Pi. Work history: 1947–50, instructor, College of Engineering, University of Colorado; 1950–55, rocket research and development, U.S. Naval Ordnance Test Station, China Lake, Calif.; 1955 to present, Head, Radiological Effects Branch, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif. Publications: Several papers and technical reports on effects of radiations on materials, properties of fallout, and radiological effects. Present residence: Palo Alto, Calif.

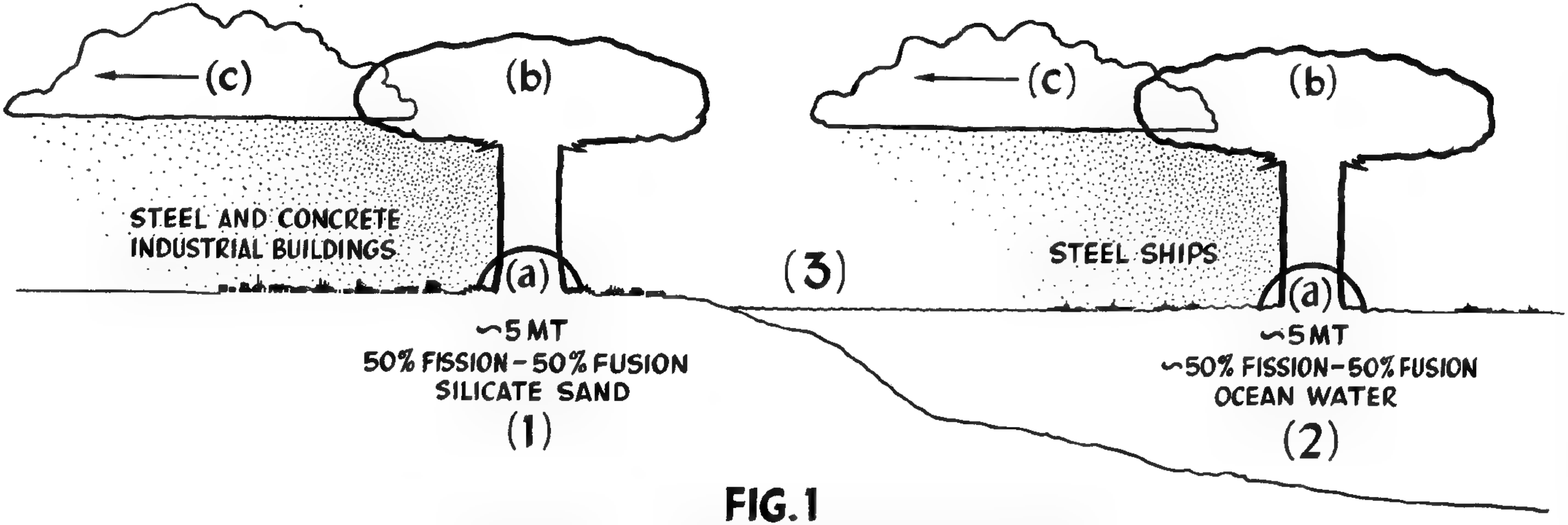
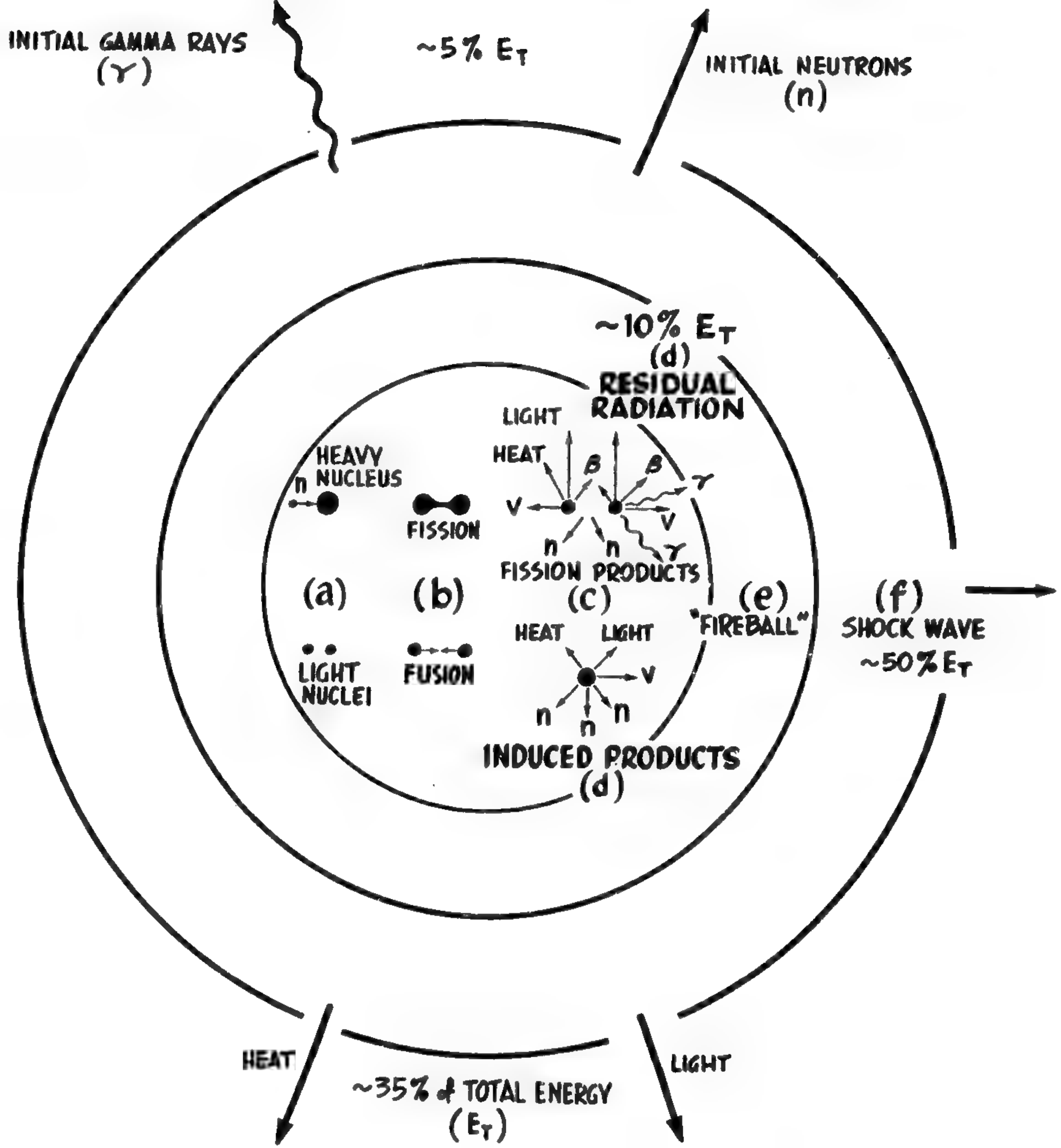


FIG. 1
ASSUMED DETONATION CONDITIONS

FIG. 2 NUCLEAR EXPLOSION PROCESSES



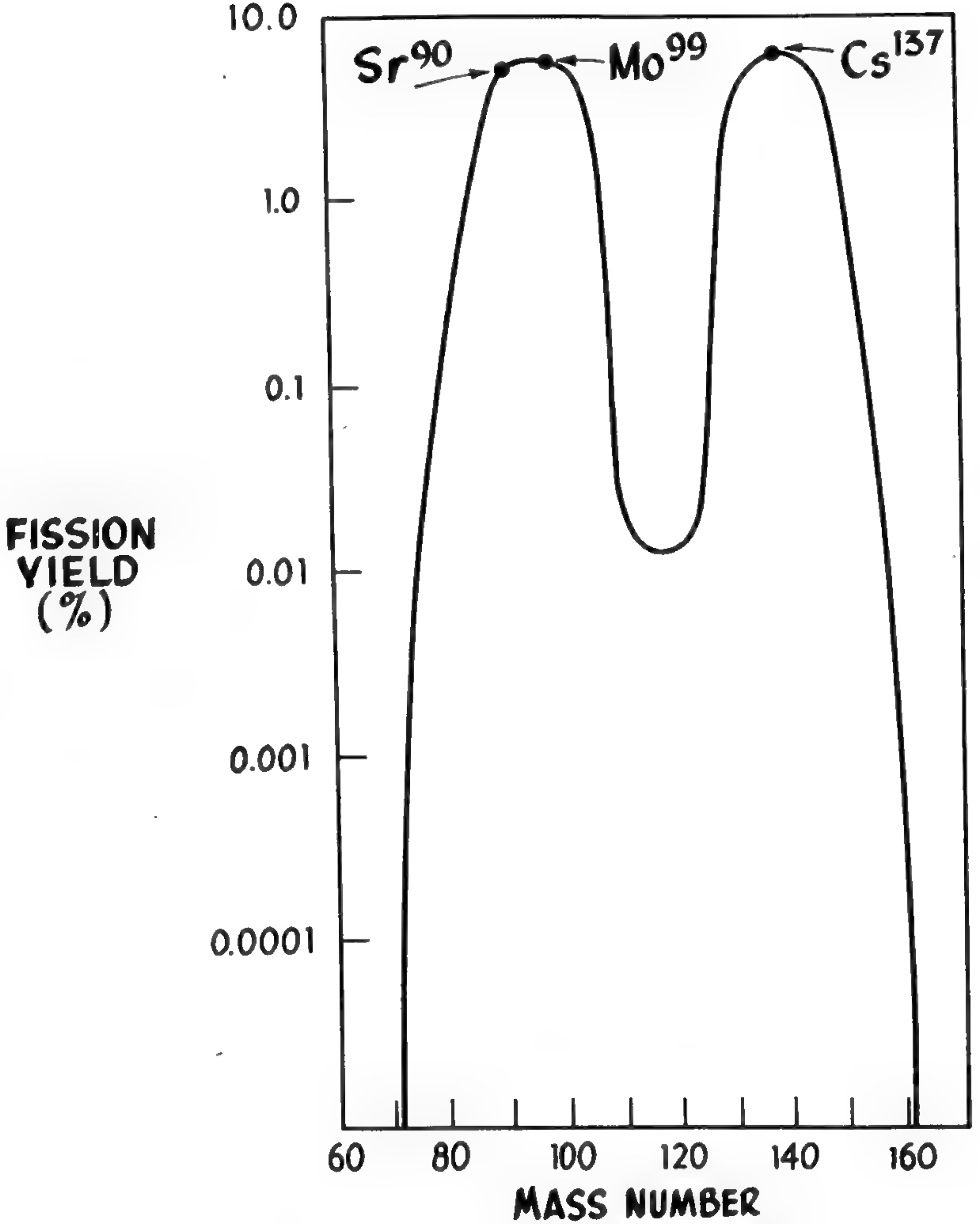


FIG. 3
FISSION PRODUCTS

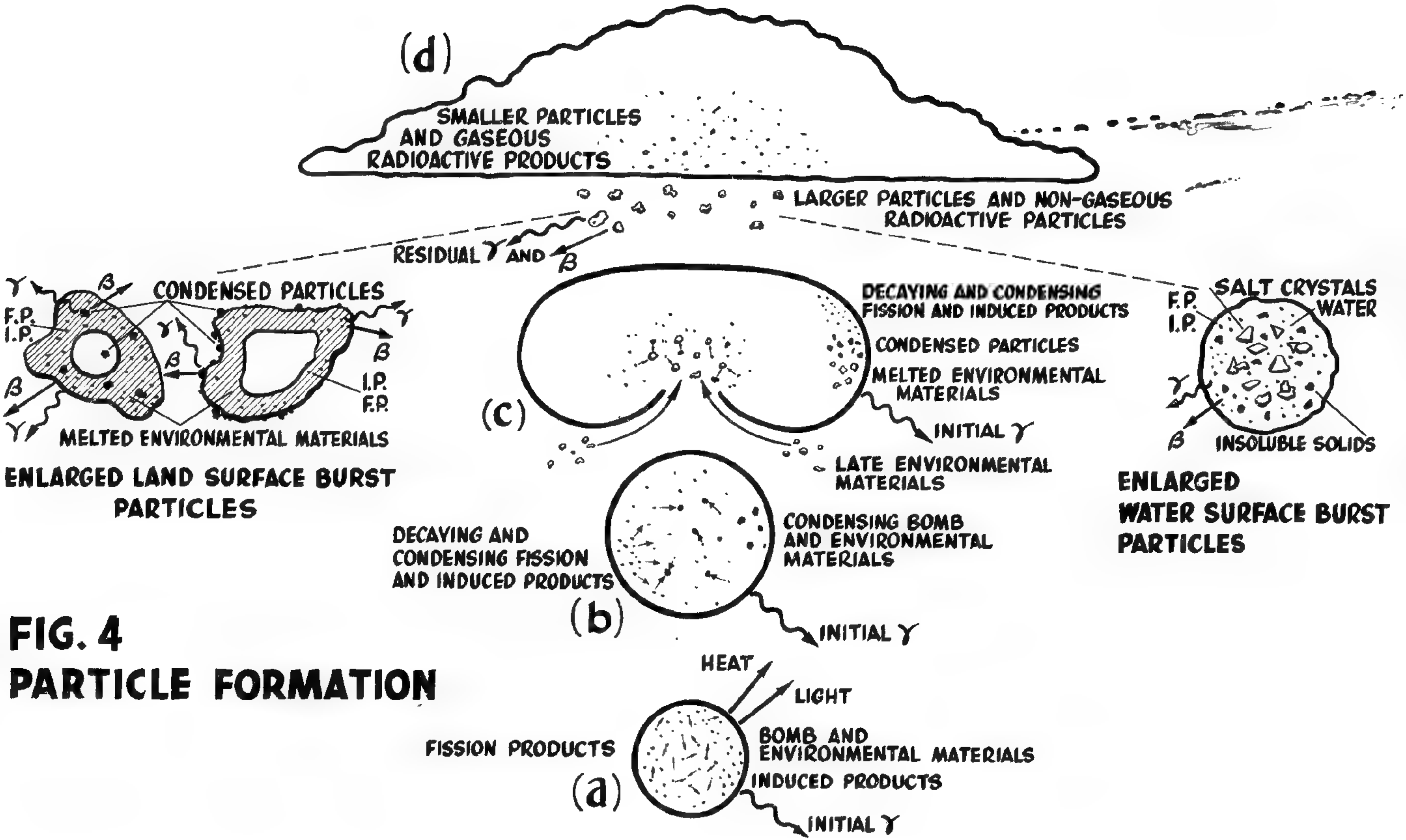


FIG. 4
PARTICLE FORMATION

References 22 and 4:
Tests (a) TEWA
and (b) SUGAR

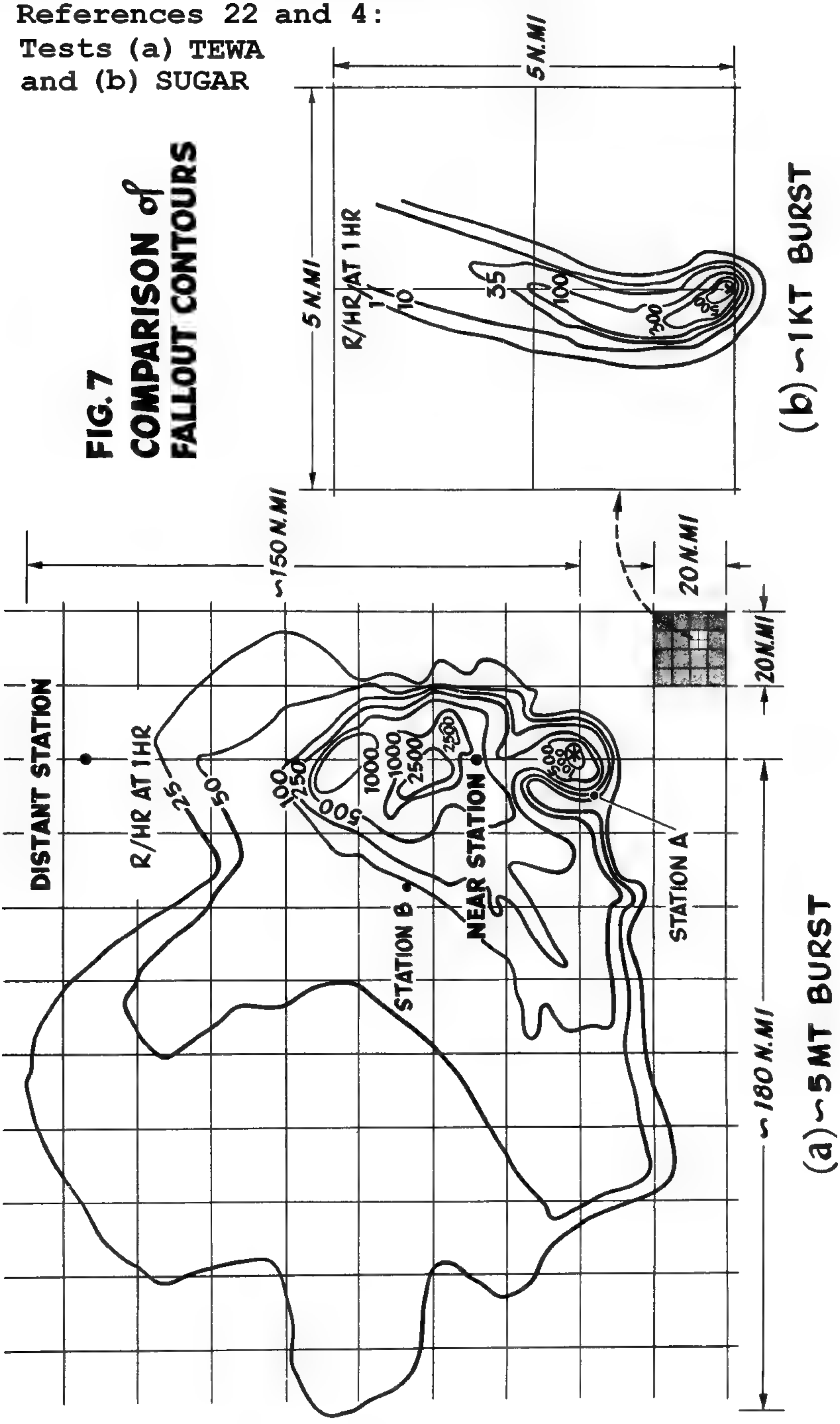


FIG. 7
COMPARISON of FALLOUT CONTOURS

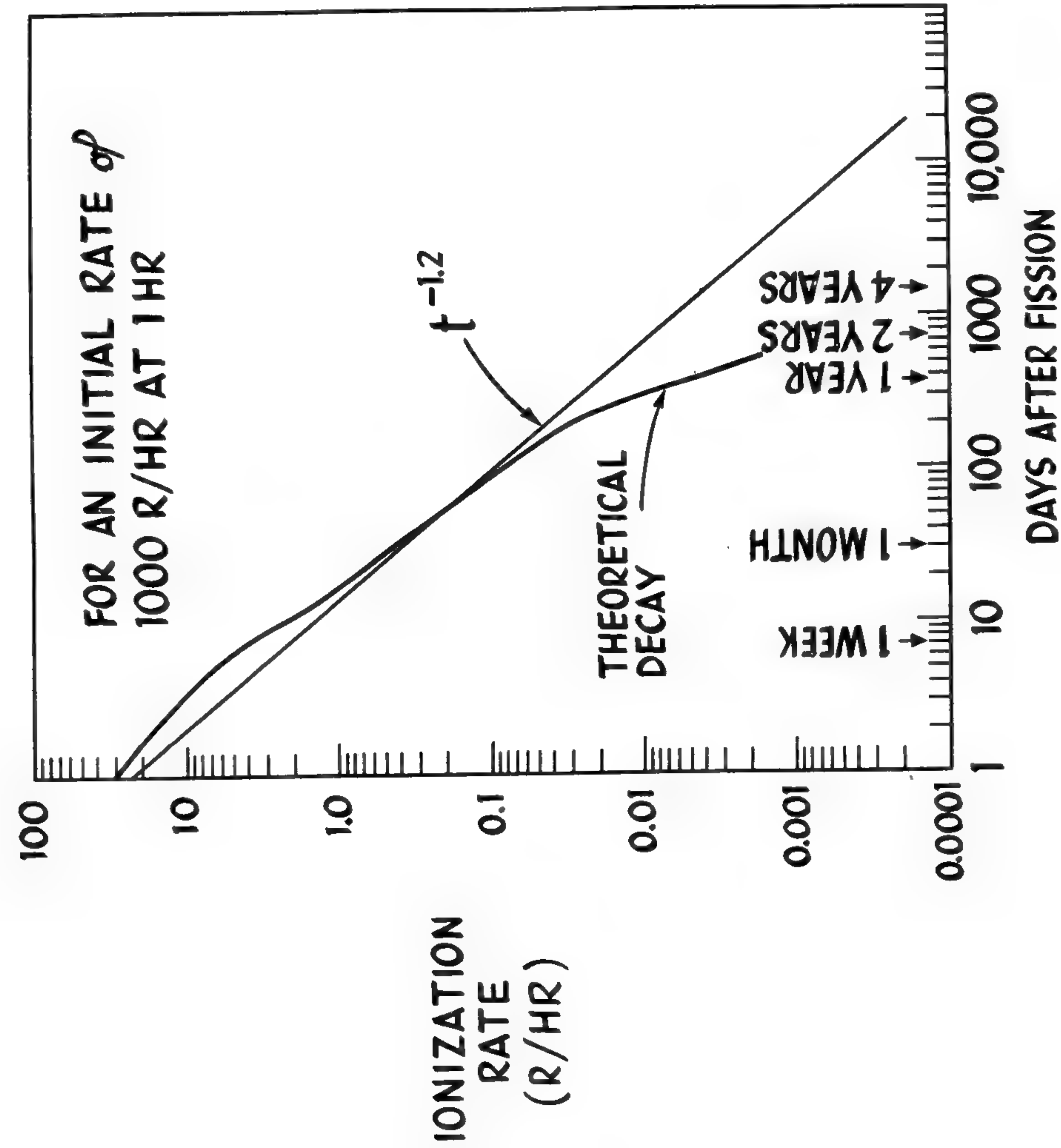


FIG. 6
RADIOACTIVE DECAY RATE

TABLE 1

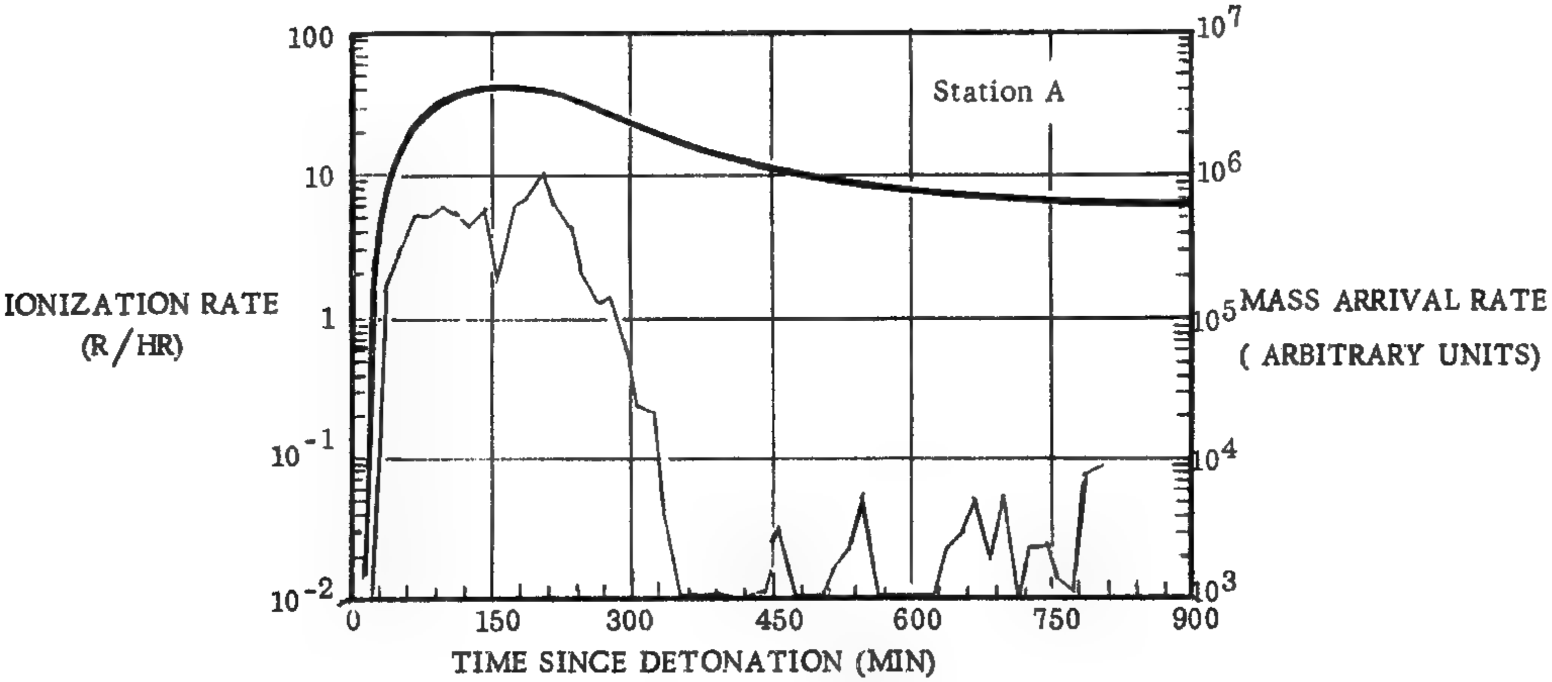
ARRIVAL CHARACTERISTICS OF LAND SURFACE BURST FALLOUT

REDWING – TEWA, 5.01 Mt (DECLASSIFIED DATA ADDED FROM TRIFFET WT-1317.)

Characteristics	WT-1317, p. 61 →	Station A ← YFNB29		Station B ← LST611
USNRDL-466, pp. 20-21 →		(~8 mi downwind) 7.84 Stat. miles WSW.		(~60 mi downwind) 59.3 Stat. miles N.W.
Time of Arrival	0.23	~0.25 hr since detonation ✓	7	~7 hr since detonation ✓
Time of Peak	2.7	~1.5 ✓ "	14	~13.5 ✓ "
Time of Cessation	16	~6 ✓ "	16	~16 ✓ "
Rate of Arrival		See Fig. 8a		See Fig. 8b
Peak Dose Rate	40	~40 r/hr ✓	0.256	~0.25 r/hr ✓
Total Mass Deposited	4.533	~4.5 gm/ft^2 ✓	0.0629	~0.06 gm/ft^2 ✓
Total Radioactivity Deposited		~2.7 x 10^{15} fiss/ft^2		~9.5 x 10^{13} fiss/ft^2

TRIFFET HAS NOT CONVERTED THESE FROM 87% TO 50% FISSION BOMB YIELD!.

TEWA shot barge YFNB29 (Triffet, WT-1317)



TEWA shot ship LST611 (Triffet, WT-1317)

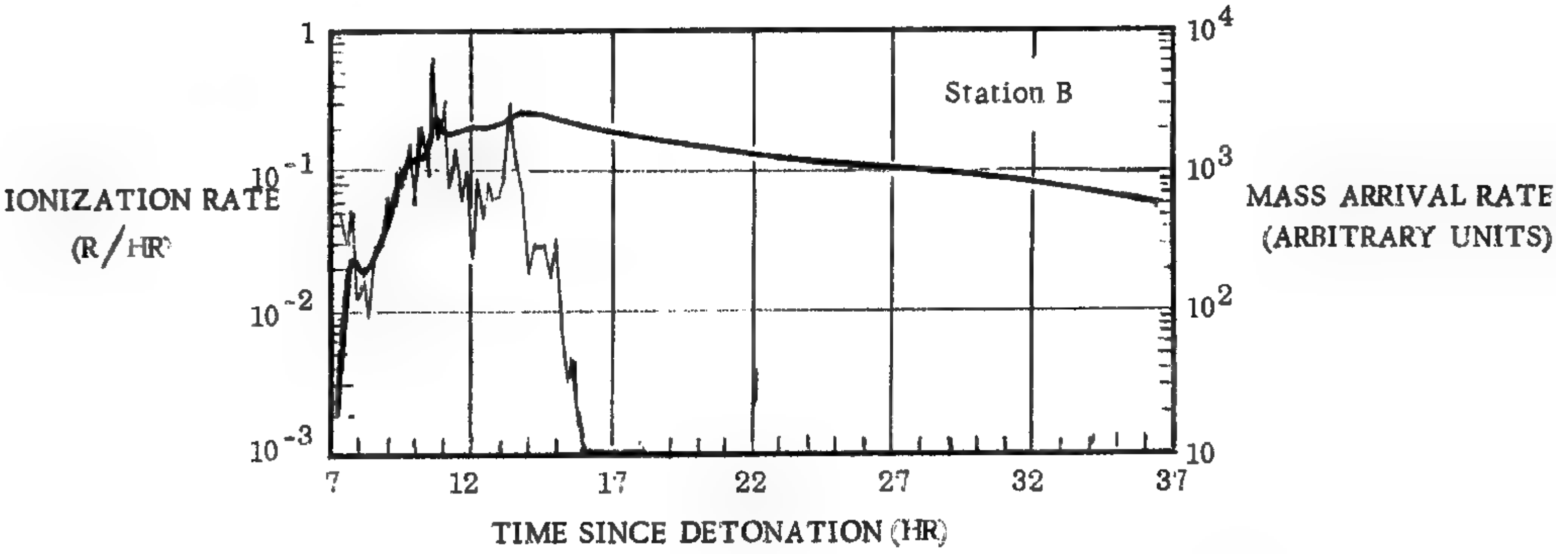


FIGURE 8 LAND SURFACE BURST FALLOUT RATE OF ARRIVAL

TABLE 2

PHYSICAL PROPERTIES OF LAND SURFACE BURST FALLOUT

Properties of Particles*	Station A ($\sim$ 8 mi downwind)	Station B ($\sim$60 mi downwind)
General Description	Melted, glassy solid containing air bubbles and mineral grains.	
Range of Diameters	$\sim$ 0.075 to 1.5 millimeter	$\sim$ 0.050 to 0.30 millimeter
Predominant Size	$\sim$ 0.35 millimeter in diameter	$\sim$ 0.10 millimeter in diameter
Color	Transparent to opaque, pale green or yellow to brown or black.	
Shape	Spherical to irregular.	
Specific Gravity	$\sim$ 1.4 - 2.6 gm/cm^3	
Distribution of Radioactivity	Irregularly throughout.	
Relation of Radioactivity to Size	$A \propto D_{max}^{\sim 3}$, but with the range of A increasing with D_{max}.	

* Based on properties of particles from kiloton bursts on silicate sand; all other information derived from megaton bursts on coral sand.

TABLE 3

CHEMICAL AND RADIOCHEMICAL PROPERTIES OF LAND SURFACE BURST FALLOUT

Properties	Station A ($\sim$8 mi downwind)	Station B ($\sim$60 mi downwind)
Principal Components	Silicates, iron oxide.	
Relative Solubility	Less than 3% of the radioactivity soluble by leaching for several days with water.	
		Nevada fallout
Principal Fission Gamma Emitters		
1-2 hr	Cs, Te, I, Nb	
13-14 hr	I, Y, Nb, Sr	
1 yr	Nb, Zr, Pr, Ba	
Beta Emitter	Sr^{90}	
Principal Induced Gamma Emitters		
1-2 hr	U^{239}, Np^{239}, Na^{24}	
13-14 hr	Np^{239}, Na^{24}, U^{237}	
1 yr	Co^{60}, Mn^{54}, Co^{58}	
Beta Emitter	C^{14}	
Relative Fractionation (Mo^{99})		
Important Products	Sr^{90}, Cs^{137}	Sr^{90}, Cs^{137}
% Depletion	$\sim$80 $\sim$85	50-65 55-65
Initial Partition-% in Local Fallout		
% Total Fissions (Mo^{99})	90-95	
% Important Products	Sr^{90}, Cs^{137} 45-70 10-30	

TABLE 4

RADIATION CHARACTERISTICS OF LAND SURFACE BURST FALLOUT

Characteristics	Station A (~ 8 mi downwind)	Station B (~ 60 mi downwind)
Ionization Decay Rate	See Fig. 9	See Fig. 9
Average Energy		
1 hr	--	~ 1.0 mev
2 hr	--	0.95
1/2 day	--	0.60
1 day	--	0.40
1 week	~ 0.25 mev	0.35
1 mo	0.45	0.65
2 mo	0.55	0.65
1 yr	--	0.55

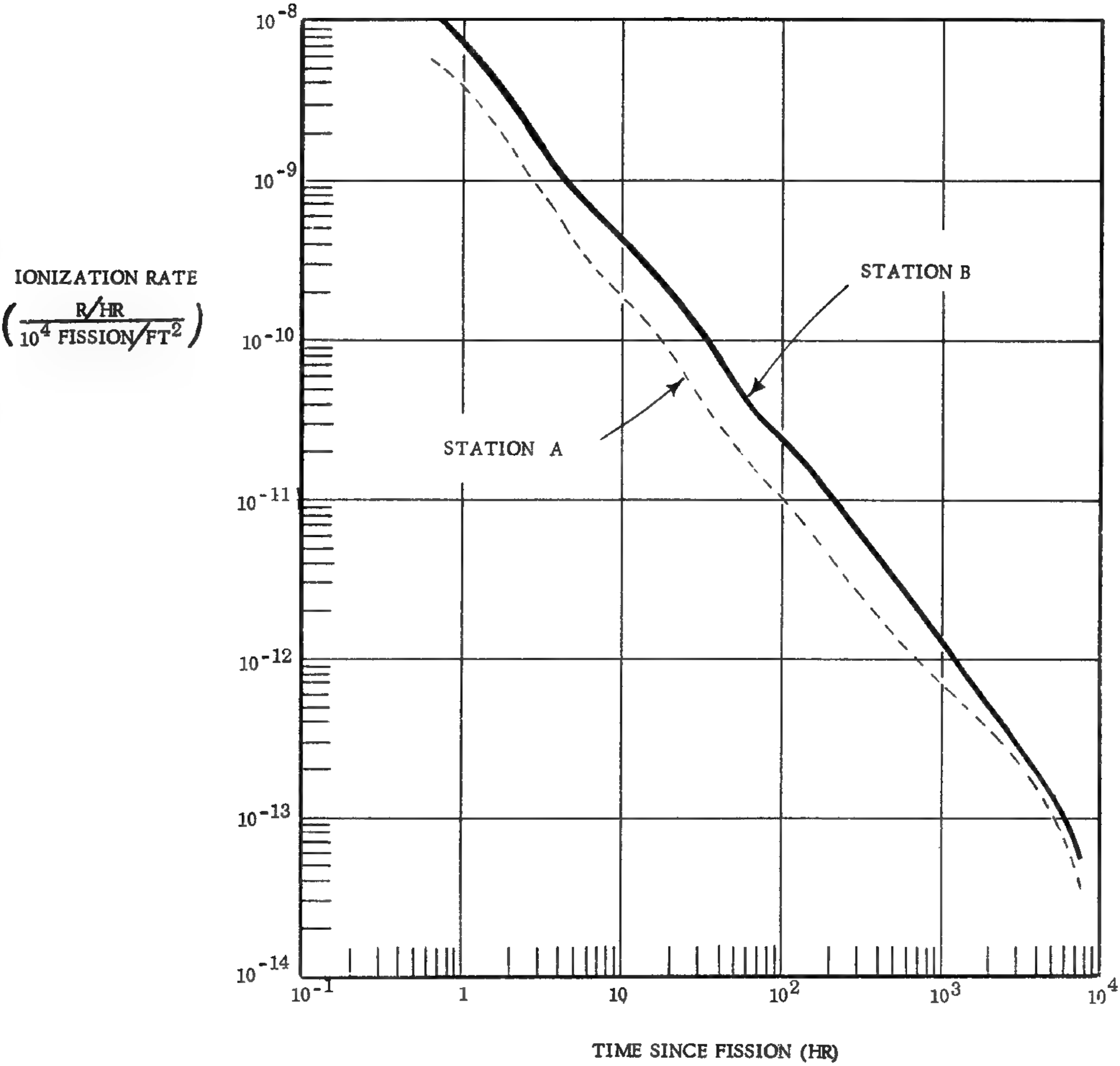


FIGURE 9 LAND SURFACE BURST RADIOACTIVE DECAY RATE

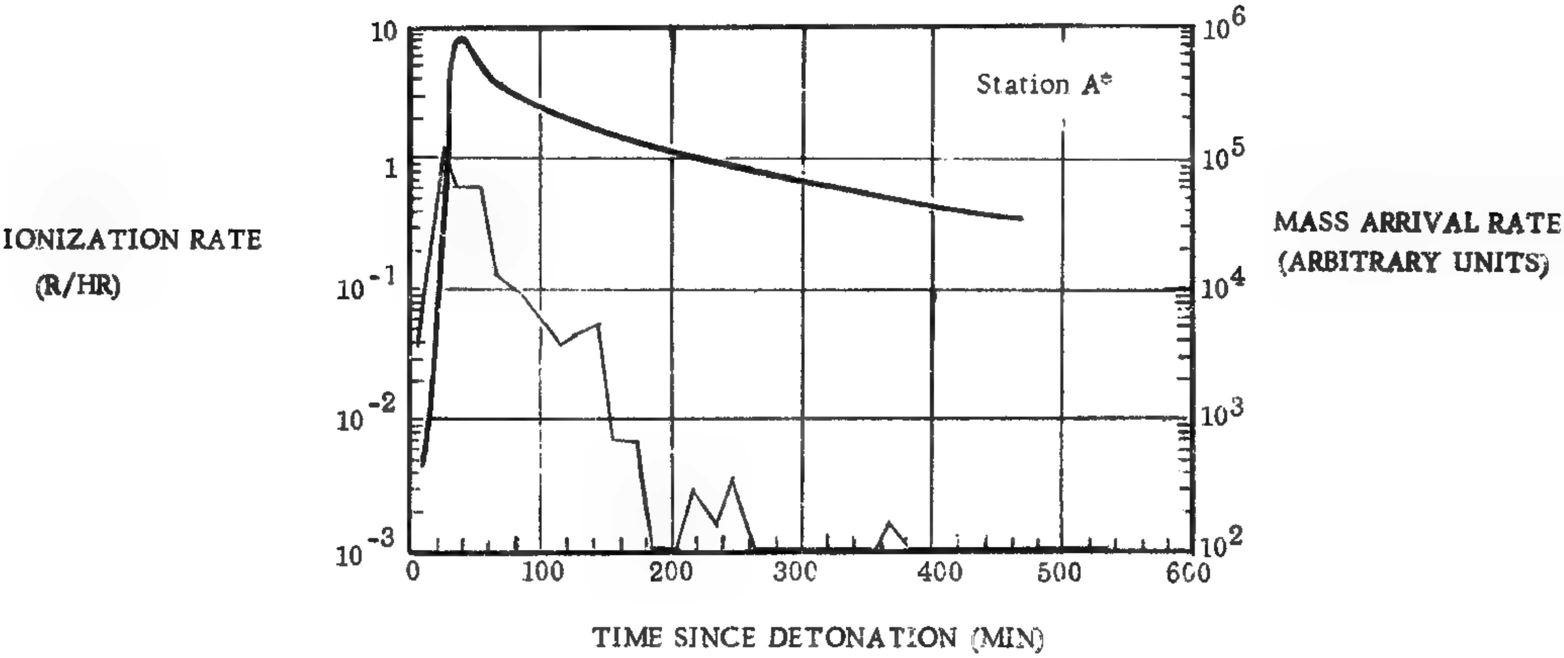
TABLE 5

ARRIVAL CHARACTERISTICS OF WATER SURFACE BURST FALLOUT

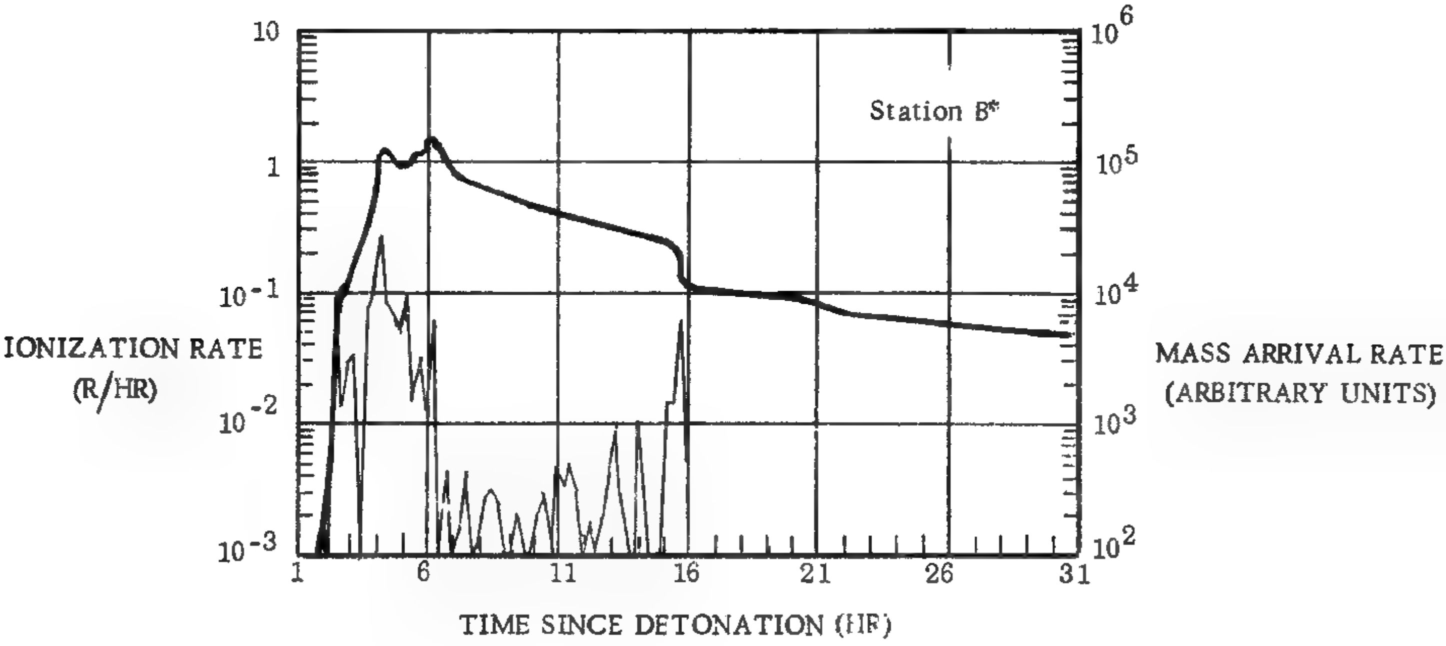
TRIFFET & LARIVIERE, WT-1317 (1961) IDENTIFIES THIS AS REDWING–NAVAJO

Characteristics	Station A* YFNB13	Station B* YAG39
Locations from WT-1317 pp. 61– & USNRDL-466 pp. 20-21. →	(~7 mi downwind) 7.54 stat. miles downwind	(~22 mi downwind) 21.0 stat. miles downwind
Time of Arrival	~ 0.20 hr since detonation ✓	~ 2.3 hr since detonation ✓
Time of Peak	0.63 ~ 0.65 ✓ " } double peak! diffusion of small particles for many hours after burst!	~ 6 ✓ "
Time of Cessation	6 ~ 3 ✓ "	~ 16 ✓ "
Rate of Arrival	See Fig. 10a	See Fig. 10b
Peak Dose Rate	~ 8.5 r/hr ✓	1.49 ~ 1.5 r/hr ✓
Total Mass Deposited	5.182 ~ 5.1 gm/ft^2	1.419 ~ 1.4 gm/ft^2 ✓
Total Radioactivity Deposited	~ 5.7 x 10^{14} fiss/ft^2	~ 1.5 x 10^{14} fiss/ft^2

* Contours not shown; similar to Fig. 7a.



NAVAJO shot, barge YFNB13



NAVAJO shot, ship YAG39

FIGURE 10 WATER SURFACE BURST FALLOUT RATE OF ARRIVAL

TABLE 6

PHYSICAL PROPERTIES OF WATER SURFACE BURST FALLOUT

Properties of Particles	Station A* ($\sim$7 mi downwind)	Station B* ($\sim$22 mi downwind)
General Description	Salt slurry droplet containing insoluble solids.	
Range of Diameters	$\sim$ 0.08 to 0.30 millimeter	
Predominant Size	$\sim$ 0.275 millimeter in diameter	$\sim$0.225 millimeter in diameter
Size Range of Insoluble Solids	0.03 millimeter in diameter to sub-microscopic.	
Color	Droplets translucent white, solids amber.	
Shape	Droplets spherical, solids agglomerated spherical.	
Specific Gravity	$\sim$ 1.3 gm/cm^3	
Distribution of Radioactivity	Approximately equal partition between soluble and insoluble components.	
Relation of Radioactivity to Size	$A \propto$ NaCl Wt.	

*Contours not shown; similar to Fig. 7a.

TABLE 7

CHEMICAL AND RADIOCHEMICAL PROPERTIES OF WATER SURFACE BURST FALLOUT

Properties	Station A* ($\sim$7 mi downwind)	Station B* ($\sim$22 mi downwind)
Principal Components	Sodium chloride, water.	
Relative Solubility	About 50% of radioactivity soluble in water.	
Solid/Liquid Wt. Ratio	~ 1	
Principal Fission		
Gamma Emitters		
1/2-1 hr	Cs, Nb, Te	
6-7 hr	I, Y, Kr, Sr, Nb	
1 yr	Nb, Zr, Pr, Ba	
Beta Emitter	Sr^{90}	
Principal Induced		
Gamma Emitters		
1/2-1 hr	U^{239}, Np^{239}, Na^{24}, Cl^{38}	
6-7 hr	Np^{239}, Na^{24}, U^{237}	
1 yr	Co^{60}, Mn^{54}, Co^{58}	
Beta Emitter	C^{14}	
Relative Fractionation (Mo^{99})		
Important Products	Sr^{90}, Cs^{137}	
% Depletion	10-30 35-50	
Initial Partition-% in Local Fallout		
% Total Fissions (Mo^{99})	65-75	
% Important Products	Sr^{90}, Cs^{137} 50-60 25-55	

* Contours not shown; similar to Fig. 7a.

TABLE 8

RADIATION CHARACTERISTICS OF WATER SURFACE BURST FALLOUT

Characteristics	Station A* (~7 mi downwind)	Station B* (~22 mi downwind)
γ Ionization Decay Rate	See Fig. 11	
Average γ Energy		
1 hr	~ 1.0 mev	
2 hr	0.95	
1/2 day	0.60	
1 day	0.40	
1 week	0.35	
1 mo	0.65	
2 mo	0.65	
1 yr	0.55	

* Contours not shown; similar to Fig. 7a.

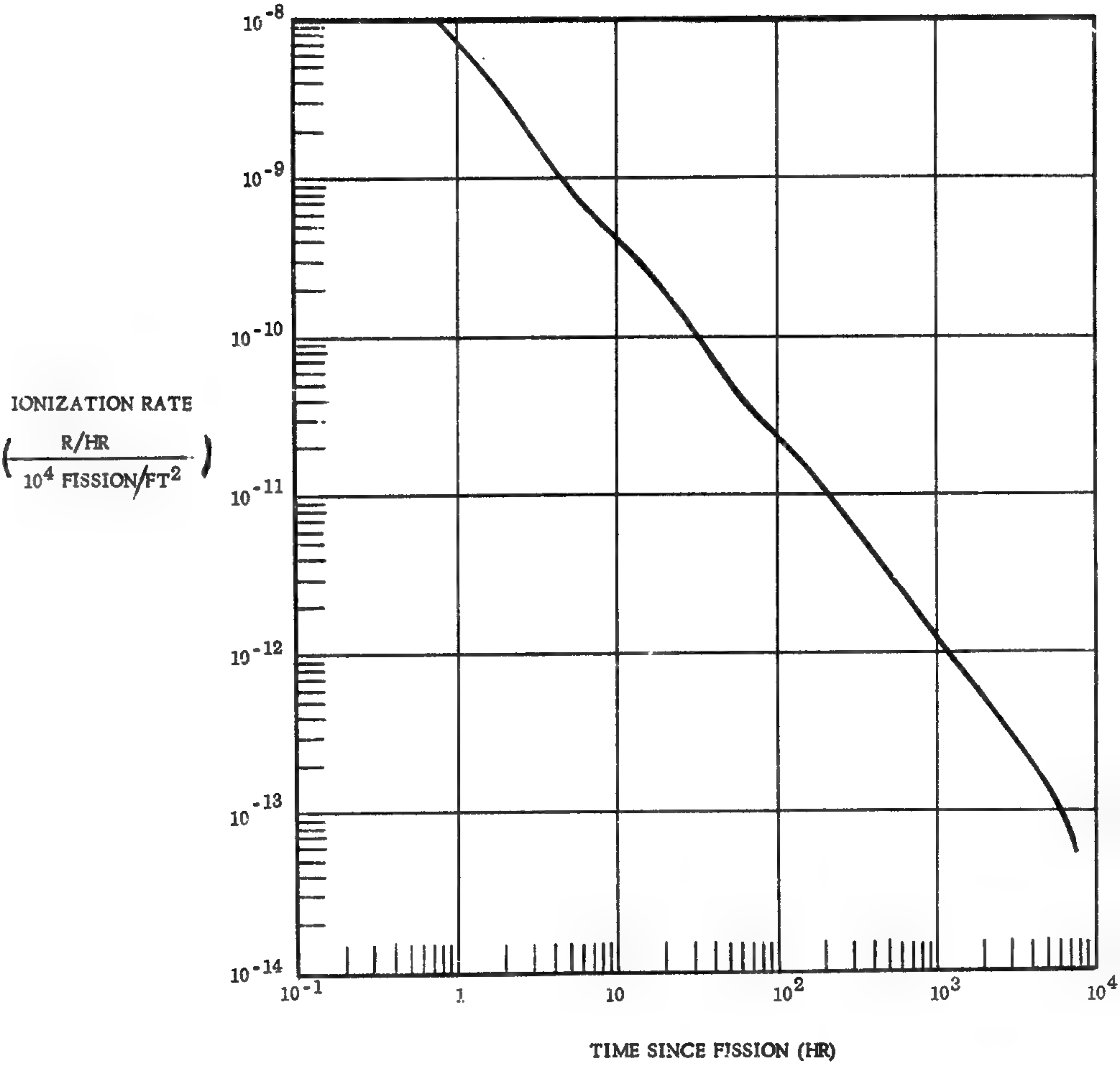


FIGURE 11 WATER SURFACE BURST RADIOACTIVE DECAY RATE

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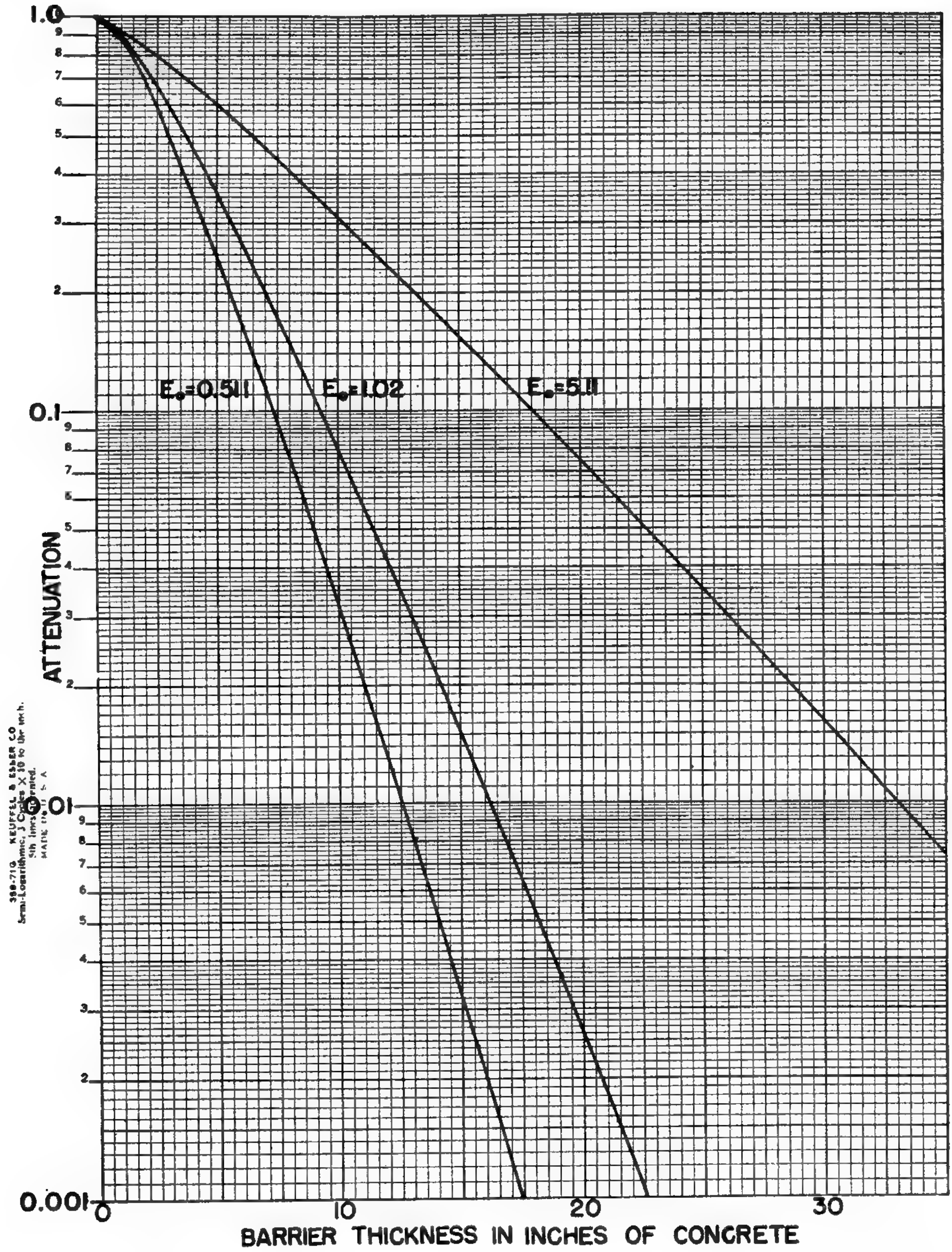

FIGURE 4.—Attenuation of gamma radiation dose as a function of concrete barrier thickness for three different gamma ray source energies. The units of E_0 are Mev. The curves were calculated for gamma radiation perpendicularly incident on the barrier

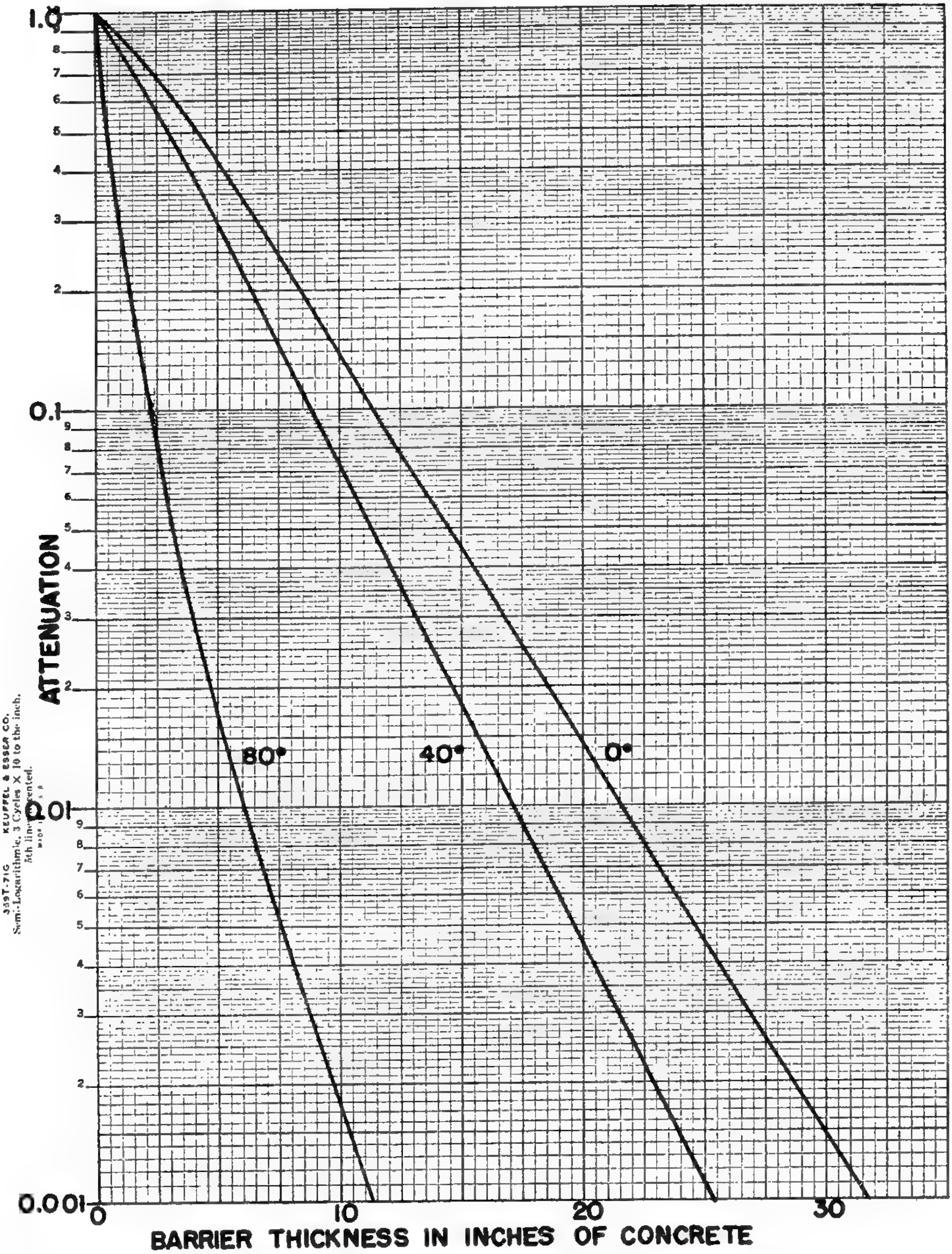

FIGURE 5.—Attenuation of gamma radiation dose as a function of concrete barrier thickness for three different angles of incidence. The curves were calculated for the energy distribution of fission product gamma rays at 1 hour after weapon burst.

III. NATIONAL ACADEMY OF SCIENCES ADVISORY COMMITTEE ON CIVIL DEFENSE, SUBCOMMITTEE ON RADIATION SHIELDING

In the problem of shielding from fallout radiation, as well as in all scientific work, it is important that the theoretical and the experimental work be closely coordinated. With this in mind, the Advisory Committee on Civil Defense of the National Academy of Sciences formed a Subcommittee on Radiation Shielding. This subcommittee is composed of people who are actively engaged in either calculations or experiments. It includes representatives from the Office of Civil and Defense Mobilization, the National Bureau of Standards, Oak Ridge National Laboratory, the Defense Atomic Support Agency, the Naval Radiological Defense Laboratory, Technical Operations, Inc., and the University of California. It was formed last October and has met approximately once every 3 months. This subcommittee also serves in an advisory capacity to OCDM in directing its research efforts on radiation shielding.

TABLE 1.—*Categorization of shelter areas*

Category	Protection factor	Typical examples
A	1,000 or greater	1. OCDM underground shelters. 2. Subbasements of multistory buildings. 3. Underground installations (mines, tunnels, etc.).
B	250 to 1,000	1. OCDM basement fallout shelters (heavy masonry residences). 2. Basements (without exposed walls) of multistory buildings.
C	50 to 250	1. OCDM basement fallout shelters (frame and brick veneer residences). 2. Central areas of basements (with partially exposed walls) of multistory buildings. 3. Central areas of floors near midheight of large multistory buildings with heavy exterior walls and floors.
D	10 to 50	1. Basements (without exposed walls) of small 1- or 2-story buildings. 2. Central areas of floors near midheight of large multistory buildings with light exterior walls and floors.
E	2 to 10	1. Basements (partially exposed) of small 1- or 2-story buildings. 2. Central areas of lower floors in large multistory buildings. 3. Central areas on ground floor in 1- or 2-story buildings with heavy masonry walls.
F	1½ to 2	1. Aboveground areas of low buildings, in general, including residences stores, factories, etc.

TABLE 2.—*Shielding factors in some typical light residential structures*[1]

[Values deduced from experiment]

Structure	Location	Reduction factors[2]			Protection factor[3]
		Roof contribution	Ground contribution	Total	
2 story wood frame house	2d floor center	0.076	0.50	0.58	1.7
	1st floor center	.034	.57	.60	1.7
	Basement center	.015	.028	.043	[4]23
1 story wood rambler	1st floor center	.10	.54	.64	1.6
2 story brick veneer house	do	.034	.14	.17	[5]6
	Basement center	.015	.021	.036	[4]28

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[1] Values in this table are from an NBS report, to be published. (Ref. 17.)

[2] Reduction factor is defined as dose rate at the specified location divided by the dose rate outside at 3 feet above the ground.

[3] Protection factor is defined as dose rate at 3 feet above the ground, outside, divided by the dose rate at the specified location.

[4] This factor applies to basements with no exposed walls.

[5] This factor applies only for detector locations below window sill level

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BASIC PROPERTIES AND EFFECTS OF RADIOACTIVE FALLOUT

FACTORS MODIFYING THE BEHAVIOR OF DEPOSITED CONTAMINANTS

(By Sanford Baum,[1] U.S. Naval Radiological Defense Laboratory)

Estimates of the radiological hazard caused by the fallout from megaton-range weapons are usually obtained either from measurements carried out in the Pacific or by the application of fallout prediction methods. In general, neither of these sources involves direct measurement of fallout which is actually deposited on a land surface. In the case of measurements from the Pacific area, most of the fallout is deposited in the ocean. It is necessary to reconstruct, from measurements of the activity left near the ocean surface, the radiation contours which would have resulted had the same deposition occurred over land. Descriptions of the hazard produced by megaton weapons must contain an assumption about the land surfaces over which fallout is expected to occur. The assumption most frequently made is that the fallout producing the hazard in a given locality is uniformly distributed over an infinitely large plane. Occasionally, this assumption is modified to take the roughness of the terrain into account. A second assumption is that, once the fallout is deposited on the plane, it remains fixed and the only changes in radiation intensity are due to radioactive decay.

When potential targets in the United States are considered, neither of these assumptions is necessarily justified. The targets contain both natural and manmade objects which obviously depart from the conditions of the first assumption. Wind, rain, or snow can either move the deposited contaminant or cover it with inert material such as snow or sand. It is recognized that all of these factors can modify the predicted degree of hazard.

The effect of weather on the deposited contaminant has been discussed by Machta and Nagler (1). Fallout particles in the atmosphere may be trapped in rain or snow. Once they reach the ground they can be washed into the ground or carried away by runoff. The latter effect is more important usually, because, once the airspaces in the ground are filled with water, most of the additional water will run off into streams, carrying along more of the radioactive particles.

Fallout deposited in the dry form can be affected by rain or snow. Significant transport will result when raindrops dislodge particles in strong winds or on slopes with as little as 10-percent grade. The winds can move the particles directly. The primary factor here is size of the fallout particle. Particles whose diameters range from 50 to 500 microns are the most easily moved. In areas of significant hazard particles in this range are responsible for most of the radiation (2). In general, the movement of these particles will result in a net lowering in the regions of high intensity and some extension of the fringe areas.

There is little quantitative information on these topics. Qualitative evidence which, in the main, supports the above conclusions have been described by Strope (3). The problem is complicated because of the variability in the meteorological parameters. In general, the effect of weather is to reduce the predicated intensities.

Experiments to determine the change in hazard caused by gross differences in natural terrain have been performed. Equal amounts of a radioactive isotope were placed in an identical manner on equal areas with varying degrees of roughness. The roughness ranged from that of a smooth concrete slab to that of a wooded hilly field. It was found that the hazard decreased with increasing roughness. At the standard height of 3 feet, the radiation from the roughest surface was two-thirds that of the smoothest. Differences caused by varying surfaces of measurement tend to disappear with increasing height. Comparisons have been made between a fallout-contaminated Nevada area and computed results based on the flat plane assumption (5). It was found that in the real case, the deposited fallout behaves as if it were uniformly mixed to some shallow depth, of the order of an inch, in the soil. This implies that the flat plane value will be too high (4, 5, 6). Another consequence of this difference is that in an

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[1] Chemist, Military Evaluations Division, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif. Date of birth: Oct. 22, 1924. Married: Two children. Education: B.S. in chemistry, University of California, 1951.

area partially free of fallout, the radiation intensity first increases and then decreases as the height of measurement over the cleared area increases. The latter consequence is of importance in considering the shelter afforded by multistory buildings. Comparisons between calculated values obtained on the basis of the infinite plane and observed radiation intensities were possible for one event and location in the Pacific (7). It was found that the ratio of observed to calculated intensities varied with time. Ratios of 0.45, 0.66, and 0.56 were found at 11.2, 100 to 200, and 370 to 1,000 hours, respectively.

The role of vegetation and trees, which could in effect elevate some of the fallout above the surrounding ground level, has been examined by Baum (8). It was concluded that the amount of radiation contributed by the fallout attached to vegetation or trees would be small when compared to that emanating from the ground. This situation was considered by Lindberg (9), whose work (10, 11) in Nevada, provided much of the data used by Baum. Lindberg also concluded that the contribution from contaminated plants would be small. It was recognized by all concerned that rather large extrapolations were required to reach the conclusion and that more direct evidence was desirable.

When the fallout occurs over a community, a number of departures from the infinite plane case are encountered. Part of the fallout that would have been deposited on the ground is now resting on roofs. This has the effect of reducing the predicted intensity by (1) placing the fallout a greater distance away from the standard measuring point near the ground, and (2) interposing material between the fallout and the measuring point. Walls interpose material between the measuring point and fallout deposited on streets and unpaved areas. The reductions achieved are dependent on the dimensions and composition of the structures and in their placement relative to one another. Methods for predicting these reductions have been published (12, 13, 14). An indication of the effect of adjacent structures, in heavily built-up urban areas, is given by the following numbers. The values listed are the reductions in intensity in an area adjacent to one or more streets.

Number of adjacent streets	1	2	3	4
Reduction of predicted intensity	0.2	0.3	0.4	0.5

Application of these numbers should be made with discretion and only after reference to the original source (12). This requirement holds for all such numbers.

In the presence of even moderate winds, vertical surfaces such as walls introduce an additional perturbation. Under these conditions more particles are, in essence, flowing toward the walls than are falling to the ground. In spite of this fact, it has been observed that the ratio of horizontal to vertical contamination may vary between 5 to 1 and 300 to 1 (3). Either the particles strike the vertical surfaces and then fall to the ground at its foot, or because of airstream effects, the particles flow around the vertical surfaces. Comparisons have been made (3) between the contamination found on horizontal surfaces at the head and foot of vertical surfaces. No significant differences were found. The investigation also found that there were no differences between the front and back sides of vertically oriented surfaces. These observations can be explained on the basis of flow around the surfaces. A theoretical study of airstream phenomena has been published (15). It predicts that 75-micron particles will deposit only on horizontal surfaces and that inhomogeneites will occur rarely and over small areas. Inhomogeneites in deposition are expected to occur with particles around the 350-micron size. The most common effect will be a decrease in deposition on the roof and lee of large buildings. No upper limit can be set on the maximum concentration which may be found under adverse circumstances. It has been reported that the best available estimate of the range of significant particle sizes in areas of hazardous fallout is 50 to 400 microns (2).

Most of the experimental evidence quoted was obtained under the conditions that exist at the test sites. Extrapolation to U.S. targets involves the deposition of a possibly different contaminant into an environment very unlike that encountered at the sites. Hopefully, the difficulties inherent in the latter circumstance can be surmounted by investigations now underway at NRDL or elsewhere. Lack of knowledge concerning the basics of the fallout formation process, precludes any definitive statement about the probable nature of the fallout from U.S. targets. Consequently the extrapolation cannot be performed with confidence. Within this limitation, it has been found that the overall effects of terrain and weather reduce the hazard predicted on the basis of current assumptions.

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Representative HOLIFIELD. At this time I will ask the panel members to come forward.

ROUND TABLE PANEL DISCUSSION ON THE BASIC PROPERTIES AND EFFECTS OF RADIOACTIVE FALLOUT

Participants: Dr. Paul Tompkins, Naval Radiological Defense Laboratory; Dr. Terry Triffet, Naval Radiological Defense Laboratory; Mr. Myron Hawkins, civil defense research project, University of California; Mr. Charles Shafer, Office of Civil Defense Mobilization; Dr. Lester Machta, U.S. Weather Bureau; Mr. L. Joe Deal, Division of Biology and Medicine, AEC; and Dr. Ralph Lapp, independent physicist.

Representative HOLIFIELD. The panel has been convened in an effort to clarify and consolidate an understanding of the specific technical points upon which an agreement exists and a clarification of those areas in which disagreement is apparent. In line with the committee's objective in bringing before the public, in an understandable

Dr. Triffet. Yes. I thought this might be an appropriate place to comment on the variation of the average energy. It is clear when you think of shielding, because the effectiveness of shielding depends directly on the average energy radiation from the deposited material. As I mentioned, Dr. Cook at our laboratory has done quite a bit of work on this. What it amounts to is that at one hour the average energy is about one Mev. This appears, by the way, in the tables that are in my written statement but that I did not present orally.

Representative Holifield. Mev. means?

Dr. Triffet. Million electron volts. At 2 hours it drops to 0.95. At a half day, to 0.6. At 1 week it drops to 0.35. Then it begins to go up again. At 1 month, it is 0.65, 2 months 0.65. The meaning of this is simply that there is a period around 1 week when if induced products are important in the bomb, there are a lot of radiations emanating from these, but the energy is low so it operates to reduce the average energy in this period and shielding is immensely more effective.

Representative Holifield. Did you have an additional comment on that, Dr. Lapp? ← LAPP TRYING TO GET MORE DATA!

Dr. Lapp. I think you would not include sodium in that category.

Dr. Triffet. No. This is an environmental effect. The activity I was referring to is an induced activity in the weapon.

Representative Holifield. I believe it was testified yesterday that the buildings 25 miles away would suffer a great deal of glass damage from a 10-megaton weapon. In view of the fact that we have several million schoolchildren in schools throughout the Nation and most of these schools have a very high percentage of exterior walls and glass, will not this constitute, within itself, one of the great hazards in this type of war? I am thinking of the areas that are far removed, as far as 15 or 25 miles, from the immediate blast damage in the central area.

Would this not constitute a tremendous damaging factor?

Mr. Deal. Mr. Chairman, I might be stealing some of Dr. White's thunder, who is testifying on the blast problem this afternoon——

Representative Holifield. We will withhold that because we don't want to steal anybody's thunder. It is bad enough to steal their radioactivity. There is one factor we considered on all these different bombs. They have been surface bursts. The factor of extension of the heat of the fireball has been predicated upon the surface atmosphere, the close-to-ground atmosphere, the thickness or humidity or other qualities in the earth's atmosphere. Would there be a difference in a bomb exploded, let us say, 25 miles in the air. I am thinking of heat transference, or 40 miles in the air, as against the transference of heat along the ground level. If so, what would that factor of five be? We recognize that the air gets thinner as it goes up and there would be less resistance to heat transference. I think Dr. Shelton testified to that. He is not here today.

Is there anybody who would like to pick that up?

Dr. Tompkins. I will start in qualitatively, Mr. Holifield. I think what would happen is that as the altitude went up the increased fraction of the total energy going out in the thermal would increase the amount of heat generated.

because we can put a hole in it. The second thing that it does is that it gives maximum blast pressures. By being close to the ground it also maximizes the fallout radiation problems.

The attack pattern we have more or less evens out all of the effects and gives a good coverage of each.

Representative Holifield. From the standpoint of striking a balance, then, you would say that this attack pattern the committee has presented is a balanced attack pattern and takes into consideration most of these factors?

Dr. Tompkins. From the standpoint of the relative weapons effects it is a good balance. This is quite apart from any military characteristics.

Representative Holifield. Mr. Shafer, you had your hand up a moment ago.

Mr. Shafer. With regard to irregularities of fallout deposition, Dr. Triffet showed yesterday an analysis of a multimegaton detonation in the Pacific in which there was a tremendous fanning out of the fallout with several hot spots.

I would like to make it clear to the committee that this particular type of wind behavior, such as exists in the South Pacific, is very atypical as far as the United States is concerned. We do not have that type of wind behavior in the United States except possibly in the Gulf States in the summertime, only one season out of four. In the particular season we had under study, the fall season, October 17, 1958, the tropical easterlies did not exist anywhere in the United States and up to 60,000 feet altitude there were no easterlies even in the high stratospheric regions. So that the pattern which Dr. Machta showed would be more typical of what we could expect. But the primary thing that I want to point out is that in the event of an actual emergency we would not go through this theoretical approach to determine the location of fallout. We would do this by monitoring. To this effect we have distributed some 90,000 survey meters to the States and the local governments, some 60,000 to the Federal Government, and an additional 60,000 to the high schools. In the event of an emergency all of these 200,000 plus instruments would be used to rapidly monitor the fallout.

Representative Holifield. Are these mostly instruments that show radioactivity but do not quantitatively measure it?

Mr. Shafer. They do both, sir. They detect it and indicate the dose rate in roentgens per hour, both gamma and beta discrimination and they indicate the accumulated dose.

Representative Holifield. How often are they calibrated, and are they dependable?

Mr. Shafer. At the present time we are developing a calibration program. Some of the States, California, New York, and others are doing very well in calibrating their instruments. We are developing a calibration instrument using 20 curies of cesium 137 which will allow all of the States to calibrate their instruments. Further, our monitoring instruments are very dependable.

As you know, we do have before the Congress at the present time legislation to get sufficient funds to procure monitoring instruments. Additional instruments will be needed this year to set up some 37,000 monitoring points across the United States. We have asked for $8.5

the "Effects of Nuclear Weapons" must be looked upon as a practical lower limit.

Local fallout consists of relatively heavy debris which is deposited near the site of detonation within 1 day. The fission yield curve is characterized by high yields in the vicinity of mass numbers 85 to 100 and 135 to 145. In the first group of mass numbers there are many primary fission products belonging to the elements bromine and krypton, while in the other group iodine and xenon head up the fission chains. Strontium 90, for example, has 33-second krypton as its birth predecessor; cesium 137 derives from a fission chain headed up by 22-second iodine, followed by 3.9-minute xenon. Because of their volatile or gaseous ancestry in the fireball or bomb cloud a number of the high-yield fission products are formed in finely divided particles. Some of these are so small that they are not subject to gravitational settling, and in fact they remain suspended in the earth's atmosphere for many years, providing[6] that they reach the stratosphere at the proper latitude. In any event such fission products would be depleted in the local fallout. It is difficult to allow for this depletion since it depends upon the magnitude and mode of the detonation as well as upon local meteorology.

ADDITIONAL RADIOACTIVITY

Little attention has been given to the hazards presented by radioactive products produced in nonfission reactions in the bomb itself, or in the local environment. In the case of the bomb material there is the hazard formed by the transuranic elements. For example, the irradiation of uranium^{238} with low Mev. neutrons forms neptunium 239, a 2.3-day radioelement which W. J. Heiman[7] estimates might constitute 50 percent of the residual activity a few days after a bomb detonation. The growth of Np^{239} in fallout is such that at 1 hour its activity would account for 0.5 percent of the total gamma rays; at 1 day this would rise to 23 percent, reaching a maximum of 50 percent at 4 days. Thereafter it would fall to 40 percent at 1 week, to 12 percent at 2 weeks and to less than 1 percent by 1 month. The radiation due to neptunium is by no means insignificant although it does turn out to be less than the dosage from fission products. This will become clear when we examine the rate of decay of the fission products.

At higher neutron energies, such as certain types of thermonuclear weapons produce, natural uranium undergoes an (n,2n) reaction which competes with fast fission in U^{238}. The data of R. J. Howerton[8] show that U^{238} has a fission cross section of 0.6 barn from 2 to 6 Mev., thereafter climbing to a plateau value of 1 barn for neutrons up to 14 Mev. At 6.6 Mev. there is a threshold for the (n,2n) reaction and the reaction has a cross section of 1.4 barns in the range of 10 Mev. The ready identification of U^{237} in fallout points to fast fission of U^{238} as a main energy source in high-yield megaton-class weapons.

Nuclear weapons necessarily contain significant amounts of elements (stainless steel, for example) which may add to the bomb's radioactivity. This induced activity is probably small although certain long-lived emitters such as cobalt 60 may be produced in significant amounts if small amounts of nickel and cobalt are present. P. O. Strom[9] and his associates have observed the presence of cobalt isotopes in local fallout from the Redwing series of tests in 1956. Presumably this radiocobalt originated in the bomb environment. The amounts of cobalt in ocean water are too small to account for the observed activity. It is interesting to note that the locally deposited cobalt 60 contributed largely to the 1- to 10-year activity in the Redwing sample.

Weapons burst close to the ground will produce a variety of induced activities. The hazard will depend upon the weapon yield, the neutron spectrum, the chemical composition of the substratum, and the depth of the burst. A harbor burst, for example, would induce the 14.8-hour sodium-24 activity which involves very energetic gamma radiation. There is a considerable range of induced activities possible, but it is futile to attempt any specific calculations since they would de-

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[6] See E. A. Martell, "Atmospheric Circulation and Deposition of Strontium 90 Debris," Air Force Cambridge Research Center paper (July 1958). See also W. F. Libby, "Radioactive Fallout," speech of Mar. 13, 1959.

[7] Variation of Gamma Radiation Rates for Different Elements Following an Underwater Nuclear Detonation," J. Colloid. Science, 13 (1958), p. 329.

[8] "Reaction Cross Sections of U^{238} in the Low Mev. Range," UCRL 5323 (Aug. 15, 1958).

[9] "Long-Lived Cobalt Isotopes Observed in Fallout," Science, 128 (Aug. 22, 1958), p. 417.

Table 6

Relation Between Overpressure and Missile Parameters

Max pressure psi	Type of missile	Velocity ft/sec geometric mean	Velocity ft/sec range	Mass, gms geometric mean	Mass, gms range	Max missile density No/sq ft
1.9	Window glass	108	50-178	1.45	0.03-10	0.4
3.8	Window glass	168	60-310	0.58	0.01-10	159
5.0	Window glass	170	50-400	0.13	0.002-140	388
8.5	Natural stones	275	167-413	0.23	0.038-22.2	35
15.0	Natural stones	692	379-1100	0.50	0.043-8.82	4.7
17.3	Natural stones	432	300-843	0.21	0.010-13.4	99.1
17.3	Irregular steel objects	240	195-301	34.5	9.0 - 86.0	3.6

Table 8

Average Velocities of Impact Against a Hard Surface Associated with 50 Per Cent Mortality of the Indicated Species of Animals with Extrapolation to Man*

Species of Animal	Average animal mass gms	Average impact velocity for 50 per cent mortality		Equivalent height of fall (approx.) ft
		ft/sec	mph	
Mouse	19	38	26	22
Rat	180	44	30	30
Guinea pig	650	31	21	15
Rabbit	2,600	31	21	15
Man (computed)	72,574 (160 lbs)	27	18	11

National Safety Council release on urban automobile accidents shows 40 and 70 per cent of fatalities were associated respectively with speeds of or less than 20 and 30 mph. - Quoted from De Haven.

*Data AEC Project, Lovelace Foundation, Albuquerque, N.M.

Table 9

The Ranges of Impact Velocities Associated with Experimental Fracture of the Human Skull

Range impact velocities ft/sec	Approx. velocity in mph	Approx. height of fall in.	Number of subjects	Fractures in per cent
13.5-14.9	9.5	37	9	19
15-16.9	10.9	48	10	22
17-18.9	12.2	61	12	26
19-20.9	13.6	75	11	24
21-22.9	15.0	91	4	9
Total			46	100

Minimum velocity with fracture - 13.5 ft/sec (9.2 mph)
Maximum velocity with fracture - 22.8 ft/sec (15.5 mph)
Maximum velocity without fracture - unstated.

Fourthly, from the findings of Ruff (84), it is possible to deduce a velocity of about 8 ft/sec (6 mph) as likely to produce spinal fracture assuming impact with a solid surface in the sitting position.

The above data encourages one to adopt an impact velocity of 10 ft/sec as a tentative threshold criteria for human damage from abrupt decelerative impact following displacement by blast-produced winds. Though arbitrarily chosen, the 10 ft/sec (6.8 mph) figure is quite likely low enough to avoid any significant number of casualties and if serious injuries occur, they are likely to be few indeed.

Empirical work by Taborelli, et al. (51, 52) in the 1957 Nevada Test Series, using 160 lb anthropometric dummies exposed at stations where measured overpressures were 5.3 and 6.9 psi, demonstrated the displacement possible to humans from nuclear blast. Table 10 summarizes the findings.

Table 10

Blast Displacement of 160 Lb Anthropometric Dummies

Max pressure psi	Max Q psi	Initial dummy position	Max horizontal velocity ft/sec	Time to max velocity sec	Displacement in ft
5.3	1.8	Standing	21.4	0.5	21.9 downwind
"IDEAL"		Prone	zero	-	None
"PRECURSOR" BLAST 6.9	15.4	Standing	not known	not known	256 downwind 44 to right
		Prone	not known	not known	124 downwind 20 to right

Even at 5 psi the maximal velocity attained in 0.5 sec by the dummy was a little over 21.4 ft/sec, which speed is well above those required to fracture the skull and lower extremities. Though the displacement velocity at 6.9 psi was not obtained in the Nevada studies, the total displacement of 124 and 256 ft for the prone and standing dummies, respectively, demonstrates the unequivocal displacement hazard which can occur following nuclear explosions.

Table 16

Comparative Weapons Effect Data
Applicable to Indicated Blast Criteria
for a 1 MT Surface Burst at Sea Level

Incident over-pressure psi	Range in mi	Initial ionizing radiation rem	Thermal radiation cal/cm^2	Blast criteria for primary, secondary and tertiary effects
1.9	5.5	<10	7.2	Displacement of man 160 lb 10 ft/sec in 28 ft
2.1	5.1	<10	8.4	Displacement of man 160 lb 10 ft/sec in 10 ft
2.2	4.9	<10	9.3	Missiles (glass) 10 gm 115 ft/sec in 10 ft
2.2	4.9	<10	9.3	Missiles (masonry) 10 lbs 10 ft/sec in 26 ft
2.4	4.6	<10	10	Missiles (masonry) 10 lbs 10 ft/sec in 10 ft
2.5	4.5	<10	11	Eardrum rupture assuming pressure reflection
4.3	3.1	<10	25	Displacement of man 160 lb 10 ft/sec in 1 ft
5.0	2.8	<10	31	Eardrum rupture, assuming no pressure reflection
6.0	2.6	<10	37	Lung damage assuming pressure reflection
15.0	1.5	500	120	Lung damage assuming no pressure reflection

Computed and prepared by Bowen(86)

ASSUMES STANDING POSTURE;
NO DUCK & COVER!

ment of the dummy was near 22 feet downwind. It was this piece of empirical information that helped greatly in getting an analytical "handle" on the "treatment" of man as a missile.

Likewise in the Nevada experience on another shot, where the overpressure was about 7 pounds per square inch the maximal velocities reached by standing and prone dummies were not determined. But the total displacement of the standing dummy was 256 feet downwind and 44 feet to the right. ← PRECURSOR BLAST WAVE!

Representative HOLIFIELD. This is what size bomb, if you remember?

Dr. WHITE. I think I will ask Mr. Corsbie if he knows the yield of that shot.

Representative HOLIFIELD. Mr. Corsbie, do you remember that yield?

Mr. CORSBIE. That was a 43 kiloton fired from about a 700 foot tower. ⇒ PLUMBBOB – SMOKY 31 AUGUST 1957.

Representative HOLIFIELD. How far was the dummy from the tower?

Dr. WHITE. This was approximately—I may have to correct this—either 3,406 feet or 3,604 feet. The correct distance was 3,406 feet.

Representative HOLIFIELD. More than a half mile?

Dr. WHITE. The measured pressure there was 6.9 pounds per square inch and the pressure of the wind, which is the difference between the pressure measured head on to the advancing shock front and the pressure measured side on, was 15.4 pounds per square inch. For orientation it is useful to know that hurricane winds of about 120 miles an hour have a dynamic pressure or "Q" of approximately 0.2 of a pound per square inch. These are tremendous winds.

Representative HOLIFIELD. Then the wind is much greater than the worst hurricanes that have hit our coasts?

Dr. WHITE. Yes. This, ignoring other factors, is a function of the overpressured yield and the range, of course. The usual quoted dynamic pressure for 5 pounds per square inch for small yields is approximately 0.5 or 0.7 pound per square inch.

Representative HOLIFIELD. How high does it go in the case of a 10 megaton?

Dr. WHITE. I can't answer that out of my head. I would have to look it up. I don't think that the Q's associated with a given overpressure like 5 p.s.i. which will occur at considerable range will be much higher than for small yields. I am no blast physicist, but I think this is the case. But the winds, however, will last much longer.

Representative HOLIFIELD. Does the lower chart on page 33 mean that a body 5.5 miles from point zero would travel 28 feet?

Dr. WHITE. Yes, which is the best current estimate for the 1 MT surface burst. That range, of course, fixes an overpressure, but that range also "fixes" a velocity of 10 feet per second, which was adopted in the criteria. Ten feet per second was chosen as the velocity at impact for just beginning casualties based on what biological information is known about impact loads necessary to fracture the skull, to fracture the heel bones and the bones of the feet, and the lower extremeties.

Representative HOLIFIELD. And in the case of the 10-megaton bomb, a body would travel 58 feet over a range of 16 miles?

Dr. WHITE. At 16 miles.

It is quite true that Americans spend a good deal of time inside; however, under some circumstances (warmer regions, summertime) sizable numbers could be outside, with portions of the skin exposed. Also, especially in the peripheral zone from the point of detonation where windows may be shattered without other serious structural damage, it may not be necessary to be outside to have material deposited on one. Fallout on a previously devastated area would present a like picture. The fallout was visible in the Marshalls; it might not be in continental surroundings. Even a thin layer of clothing protected the Marshallese from visible damage from fallout from the particular device employed. I do not know to what degree the beta energy spectrum from this device would represent closely that from more recent devices. One cannot ignore the possibility of fallout coming down in rain, in which event clothing, if not removed, might provide the ideal situation for severe beta lesions. It is entirely possible under the chaotic conditions that would exist following attack that no facilities for adequate decontamination may be available. An educated, prepared population under almost any circumstances can do much to lessen the degree of damage or avoid damage completely; however, in the author's opinion, the vast majority of Americans are neither prepared for, nor educated to the danger of fallout in general, let alone the possible hazard from beta radiation.

The main point to be made from the above remarks is that while beta lesions, considered in the overall possible casualty situations, undoubtedly is a lesser consideration, it is still possible that appreciable segments of the involved population might develop beta lesions if exposed to fallout and no preventive measures were taken. If this be the situation, the results potentially could be more serious than in the Marshallese, and much more than a mere nuisance, for the following reasons: in the Marshallese, while the white count of the blood was markedly depressed, this and other immune mechanisms apparently were never impaired to the point at which the individual was not able to ward off possible invading organisms. Further, the point of maximum effect on the white count occurred relatively late, in the fifth and sixth week, after the beta lesions were well on the way to healing. With a larger dose of gamma radiation, and had the Marshallese been only a few miles further north than they were at the time of fallout they would have received a considerably larger dose, the situation might have been different. The white count would have fallen faster, and it and other immune mechanisms would have been seriously affected. Then more of the lesions might have become infected, and in addition the open lesions would provide a portal of entry for invading organisms, leading potentially to generalized infection. Infection is the problem of perhaps greatest magnitude with massive total body gamma exposure, and with open skin lesions many might succumb that otherwise might survive. This especially under conditions that undoubtedly would pertain, in which no, or inadequate, medical care would be available. Thus, at present, I do not think we should ignore completely the beta lesion problem.

In summary, there can be no doubt that in a fallout field, within hours and perhaps days of detonation, penetrating gamma radiation is the controlling hazard. Gamma radiation is the agent that kills primarily. However, there also is no doubt that extensive beta lesions have occurred, and might occur under some conditions in a fallout field. In an unprepared population unaware of the potential danger, beta skin lesions could represent a potentially serious hazard to appreciable numbers of individuals exposed. In a well-prepared population educated to the potential hazard, the beta skin lesion problem would be minimal indeed.

SUMMARY

The Marshallese accident in March 1954 demonstrated clearly that extensive beta lesions of the skin, in the absence of a lethal dose of gamma radiation, can occur under some conditions in an unprepared population exposed to a high-level fallout radiations. The fallout began on Rongelap Atoll in the Marshall Islands approximately 5 hours after the detonation of a high yield thermonuclear device, and the 64 individuals on this atoll were evacuated approximately 2 days later. An estimated 175 r. of penetrating gamma radiation was delivered to the entire body, in addition to large doses of beta radiation to exposed areas of skin to which the fallout material clung. Beginning approximately 2 weeks after exposure, lesions of the skin appeared on some 90 percent

MEDICAL SURVEY OF RONGELAP PEOPLE, MARCH 1958, FOUR YEARS AFTER EXPOSURE TO FALLOUT

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MEDICAL SURVEY OF RONGELAP PEOPLE, MARCH 1958, FOUR YEARS AFTER EXPOSURE TO FALLOUT

Background

This report presents the results of a medical survey carried out in March 1958 on the Marshallese people of Rongelap Atoll who were accidentally exposed to radioactive fallout in March 1954. The accident occurred following the detonation of a high yield thermonuclear device during experiments at Bikini in the Pacific Proving Grounds. An unpredicted shift in winds caused a deposition of significant amounts of fallout on four inhabited Marshall Islands nearby and on 23 Japanese fishermen aboard their fishing vessel, the Lucky Dragon (see Figure 1.) Sixty-four inhabitants of the island of Rongelap, 105 nautical miles away from the detonation, received the largest fallout exposure: an estimated dose of 175 r whole-body gamma radiation, beta burns and epilation from contamination of the skin, and slight internal absorption of radioactive material. Another 18 Rongelap people away on a nearby island (Ailingnae), where less fallout occurred, received only about half this exposure. Twenty-eight American servicemen on the island of Rongerik further away received about the same amount of radiation as did the 18 people on Ailingnae (about 70 r). Lastly, 157 Marshallese on Utirik, about 200 miles distant, received only about 14 r whole-body radiation. The fallout was not visible on this island and no skin effects were seen.

The exposed people were evacuated from these islands by plane and ship about two days after the accident and taken to Kwajalein Naval Base about 200 miles to the south, where they received extensive examinations for the following 3 months. In view of the generally negative findings on the American servicemen, they were returned to their duty stations. The Utirik people were repatriated to their home island, where the radioactivity was considered to be low enough for safe habitation. Because Rongelap Atoll was considered to be too highly contaminated, a temporary village was constructed for the Rongelap people on Majuro Atoll several hundred miles to the south, where they remained for the following 3½ years. In July 1957, after careful evaluation of remaining radiological hazards, Rongelap Island was found safe for habitation. A new village was constructed, and the Rongelap people were moved there by Navy ship. The present survey was therefore carried out at Rongelap Island.

SUMMARY OF PAST FINDINGS

Reports have been published on the findings of surveys made at the following times after exposure: initial examinations,[1] 6 months,[2] 1 year,[3] 2 years,[4] and 3 years.[5] The following is a brief summary of these findings.

During the first 24 to 48 hr after exposure, about ⅔ of the Rongelap people experienced anorexia and nausea. A few vomited and had diarrhea. Many also experienced itching and burning of the skin and a few complained of lachrymation and burning of the eyes. Following this, these people remained asymptomatic until about 2 weeks after the accident, when cutaneous lesions and loss of hair developed due largely to beta irradiation of the skin. It was apparent when the people were first examined, a few days after exposure, that the lymphocytes were considerably depressed and that significant doses of radiation had probably been received. In addition to the whole-body dose of radiation and the beta irradiation of the skin, radiochemical analyses of the urine showed that significant amounts of radioactive material had also been absorbed internally. The effects of the radiation can best be summarized under three headings according to the mode of exposure: penetrating irradiation, skin irradiation, and internal irradiation.

Penetrating Irradiation

The changes in the peripheral blood of the more heavily exposed Rongelap people who received 175 r will be reviewed below (see Figures 7, 9, 12 and Tables 3, 4, 5). The changes in the Ailingnae and Utirik groups were similar but less marked. Certain unexplained fluctuations have occured from year to year in the peripheral blood levels of the comparison populations as well as of the exposed groups. Depression of the peripheral blood elements as represented by mean population levels occurred as follows.

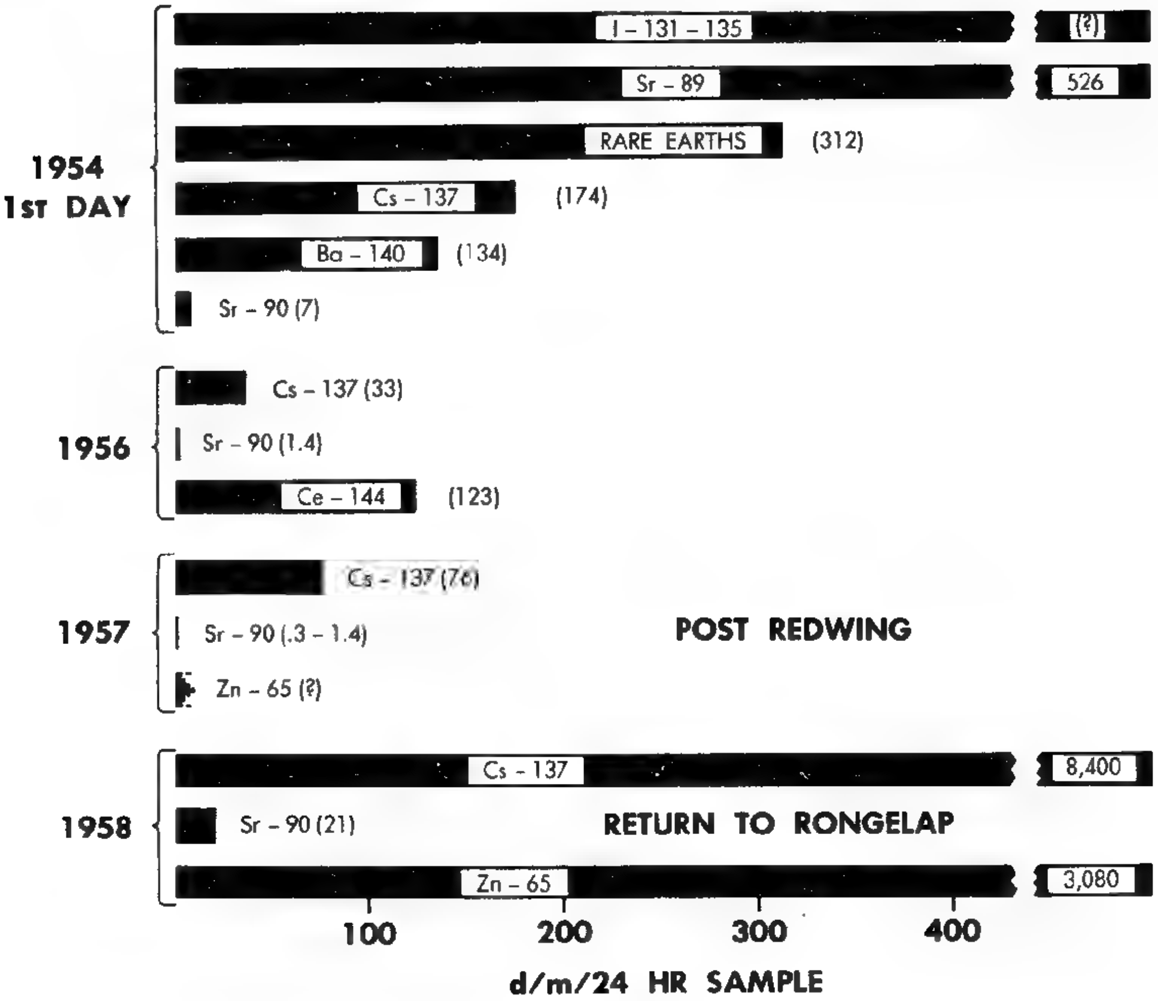

Figure 19. Urinary excretion of isotopes by Rongelap people.

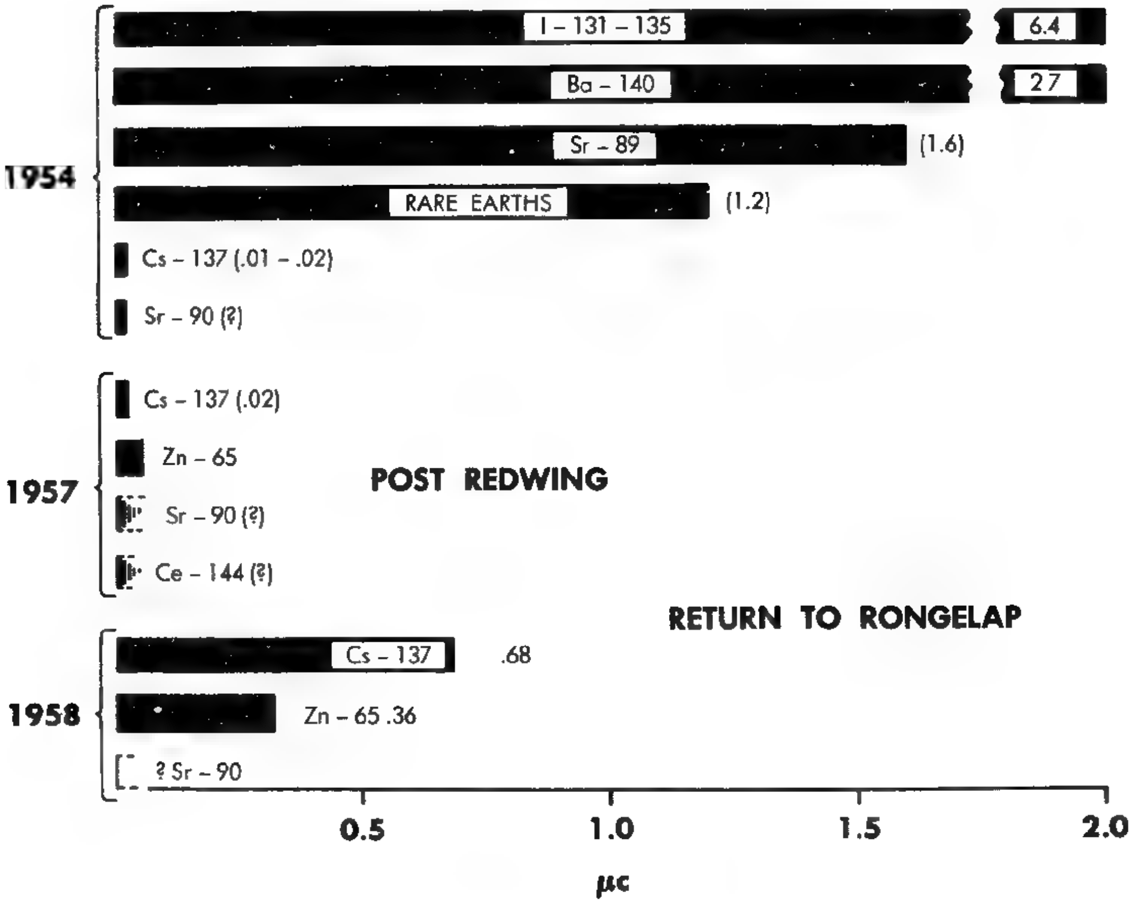

Figure 20. Estimated body burden of isotopes of Rongelap people.

DR DUNNING:

Iodine-131

1. 2 KT/mi^2 -----> 2 x 10^5 curies I^{131}/mi^2

   -----> 7.7 x 10^4 μc I^{131}/M^2

2. Based on Windscale experience

   1 μc I^{131}/M^2 -----> 0.1 μc I^{131}/liter of milk(5)

   For one liter of this milk -----> 2 rad dose to infant's thyroid.*

   For continuous consumption of milk from cows grazing on pasture until I^{131} activity essentially zero -----> 22 - 44 rad dose.*

3. Arithmetically -

   (7.7 x 10^4) (22-44) -----> (1.7-3.4) x 10^6 rads total dose to thyroid of children.

4. Based on data from nuclear weapons tests, the cow's thyroid might theoretically receive a dose two orders of magnitude higher than the human.(6)

Actually, of course, the external gamma exposure and the dose to the cow's digestive organs would guarantee its death. If milk were obtained before its death there might be enough I^{131} activity in a single pint of milk to completely destroy the infant's thyroid.

(7.7 x 10^4) (1-2 rads) -----> (7.7-15) x 10^4 rads

The short-lived isotopes of radioiodine could contribute more dose to the thyroid than does I^{131} for the first day or so, but their activity would decrease rapidly with time.(7) Milk as a food item should be avoided until the iodine activity levels dropped to acceptable limits, or canned or powdered milk (prepared before the fallout occurred) should be substituted.

5. If one assumes all contaminated milk is eliminated from the diet there remains the general I^{131} contamination of the environment including exposed foods and water.

The principal potential source of intake of the I^{131} would be leafy vegetables and other similarly exposed foods. This I^{131} contamination would be reduced by washing the foods, since the water supply would be expected to contain less I^{131} activity due to dilution factors. However, the reduction would have to be considerable since a single intake of I^{131} from one square meter of surface during the first week after the fallout occurred might produce a thyroid dose of more than 10^5 rads to the adult thyroid. It is not being postulated here that persons normally lick over a square meter of surface, but it illustrates the very heavy contamination that might exist in the environment, and that prevention of entry of significant amounts into the body would be a serious consideration.

6. Based on radiological decay only, it would require about 80 days for the I^{131} activity to decay by a factor of 1000. Even considering weathering effects it is doubtful if pasture lands would be useable by then, since doses in the order of a few hundred rads to the infant's thyroid may be carcinogenic.(8)

Thyroid Dose From Continuous Intake of I^{131} at a Daily Rate Decreasing Proportionally to the Radiological Decay

Assumptions

1. An infant will drink 1000 milliliters of milk per day from the same source.
2. The mass of the infant's thyroid is two grams.
3. Thirty percent of the ingested I^{131} will be deposited in the thyroid. (This is on the low side. Studies have shown twice this value for some children).(9)
4. The thyroid is uniformly irradiated. (Some areas may receive higher than this "average" dose).

Step 1. Calculate the initial dose rate to produce 1.0 rad total dose to the thyroid.

$$D = \frac{R_o}{(\lambda_r)\ (\lambda_r + \lambda_b)}$$

where D = total dose

R_c = initial dose rate

λ_r = radiological decay constant

λ_b = biological decay constant

$$1 = \frac{R_o}{(8.66 \times 10^{-2})\ (8.66 \times 10^{-2} + 3.85 \times 10^{-3})}$$

$$R_o = 7.8 \times 10^{-3} \text{ rads/day}$$

Step 2. Calculate the uptake of I^{131} by thyroid to produce 7.8×10^{-3} rads/day

$$\frac{x\ (\mu c)\ (2.2 \times 10^6 \times 60 \times 24)\ (d/day/\mu c)\ (0.22)\ (Mev)\ (1.6 \times 10^{-6})\ (ergs)\ (Mev)}{100\ (ergs/gm/rad)\ (2)\ (gms)} = 7.8 \times 10^{-3} \text{ rads/day}$$

$$x = 1.4 \times 10^{-3}\ \mu c$$

Step 3. Calculate the concentration per liter to result in uptake of 1.4×10^{-3} μc to the thyroid.

(1.4×10^{-3}) $(3.3) = 4.6 \times 10^{-3}$ μc intake to body to result in one rad dose to thyroid

0.1 μc/1 = 22 rads (44 rads if 60% uptake is assumed)

For the case of a single intake of I^{131}

$$D = \frac{R_o}{(\lambda_r + \lambda_b)}$$

Thus, 0.1 μc/1 -----> 1.9 rads (3.8 rads if 60% uptake is assumed)

Gross Fission Products

1. Accompanying the ingestion of I^{131} would be the other radioisotopes found in mixed fission products. The beta emissions from these isotopes would irradiate the gastrointestinal tract. Based on unfractionated mixed fission products,* the radiation dose to the lower large intestine would be roughly a factor of two less than to the adult thyroid from I^{131} for intake during the first weeks after the fallout occurred. After this period the relative dose to the intestine from gross fission products would exceed that to the thyroid from I^{131}. The adult intestine is a much more radiosensitive organ than the thyroid, with 1000 - 2000 rad dose seriously threatening life.(10)

2. Very roughly -

   a. At, say, one week after fallout occurred

      $2\ KT/mi^2 \dashrightarrow 5 \times 10^4\ \mu c/ft^2$

   b. Beta activity intake at one week to produce 1 rad to lower large intestine(11)

      $\dashrightarrow 25\ \mu c$

   c. Based on above figures -

      If the activity from one square foot of surface were ingested, death would be imminent.

~~3. Although this paper does not consider directly the effects on livestock, it will be realized that the doses from external gamma radiation in these areas of heavy fallout will essentially guarantee elimination of animals as a major source of food. A quantitative evaluation of the useability of~~

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*This condition might be approached for surface contamination but would not hold for milk contamination due to the discriminatory effect in the cow.

D. Strontium-90

1. General.

   2 KT/mi^2 -----> 200 curies Sr^{90}/mi^2

   Due to fractionation there may be 2 - 3 times less than this for the close-in areas, i.e. 67-100 curies Sr^{90}/mi^2

2. 80 mc/mi^2 -----> 8 S.U. in children (in equilibrium)* (17) or 10 mc/mi^2 ----> 1 S.U. in children. This is based on U.S. diet including milk as a major source of calcium. Use of other foods as a source of calcium would increase the Sr^{90} intake due to less discriminatory factors.(18)

3. Using 200 curies Sr^{90}/mi^2 and conversion factor

   10 mc/mi^2 -----> 1 S.U. at equilibrium.

   20,000 S.U. -----> 20 r/yr to bone marrow**

   -----> 470 r in 35 years (assuming(a) mean life of surviving population in 35 years, and a radiological decay of Sr^{90} in environment and in man).***

4. The above estimates do not consider any decontamination measures, selection of lesser contaminated foods for consumption, or use of foods from lesser contaminated areas. One may assume these factors will reduce the above estimates by whatever degree we wish to postulate the effectiveness of the factors.

* Equilibrium in children might be reached in 2 - 3 years. Equilibrium would be approached in adults only after many years and to this extent calculations overestimate the effect.

** This may be a somewhat low estimate.

***The biologically available strontium would be expected to decrease naturally with time faster than its radiological decay would indicate, therefore, the assumption used here tends to overestimate the exposure.

Where: R_o = initial dose rate to bone marrow (20 r/yr).

t = time (years) after start of irradiation.

λ = radiological decay constant.

$$D_r - \text{yrs} = \int_0^{35} R_o \, e^{-\lambda t} \left[35 - t \right] dt$$

$$D_r - \text{yrs} = 35 \, R_o \int_0^{35} e^{-\lambda t} \, dt - R_o \int_0^{35} t e^{-\lambda t} \, dt$$

$$= \frac{35 \, R_o}{\lambda} \Big[e^{-\lambda t} \Big]_{35}^{0} - R_o \left[\frac{t e^{-\lambda t}}{\lambda} + \frac{e^{-\lambda t}}{\lambda^2} \right]_{35}^{0}$$

$$\overset{\sim}{=} 9{,}400 \text{ r - years}$$

E. Other Bone Seekers.

The two other principal bone seeking radioisotopes (strontium-89 and barium-140-lanthanum-140) are not included since they contribute such a relatively small additional dose when intake is considered over a period of time.

RELATIVE DOSES TO THE BONES FROM STRONTIUM-90, STRONTIUM-89, BARIUM-140-LANTHANUM-140(a)

	Single Intake at D + 1 day			Continuour Intake from 1st day - 35 yrs.(c)
	Relative activity at D + 1 day	Relative dose rate to bone(b)	Relative total doses to bones(b)	Relative total doses to bones
Sr^{90}	1	1	1	1
Sr^{89}	180	100	1.9	0.018
Ba^{140}-La^{140}	1100	320	1.4	0.0033

(a) No fractionation assumed.

(b) Considering relative half-lives, energies and percent uptake to the bones.

(c) Assuming radiological decay of isotopes in the environment.

F. Cesium-137 (external)*

1. General.

2 KT/mi^2 $\xrightarrow{\sim}$ 400 curies Cs^{137}/mi^2

Due to fractionation this may be 2 - 3 times less for the close-in areas, i.e. 133 - 200 curies Cs^{137}/mi^2.

2. External exposure.

Roughly 1 megacurie Cs^{137}/mi^2 $\xrightarrow{\sim}$ 4r/hr

$$R = (4 \times 10^{-4})\ (4) \longrightarrow 1.6 \times 10^{-3}\text{r/hr}$$

$$D_{35}\ \text{yr.} = \frac{38}{7.03 \times 10^{-5}} \left[1 - e^{-(7.03 \times 10^{-5})\,(365)\,(35)} \right]$$

$$= 3.20 \times 10^{5}\ \text{mr}$$

$$= 320\ \text{r per 35 years}$$

3. These calculations are based on an infinitely flat plane and no account is taken of weathering and shielding effects or of decontamination measures. Actual exposures might be as much as an order of magnitude less than the theoretical dose.(13) Based on similar calculations as for Sr^{90} irradiation of the bone marrow and a reduction factor of about 7** for shielding and weathering effects:

Leukemia ~ 0.13%

Bone Cancer ~ 0.03%

* Gamma dose from shorter lived isotopes is included in the section "External Gamma Exposure."

** To simplify calculations this factor is applied starting the first year although weathering effects would not be completed by then.

4. Internal exposure.

a. Intake of Cs^{137} is more a function of the rate of fall than total deposition. This is because Cs^{137} is very poorly absorbed from the soil and the intake is more a function of surface contamination than of foodstuff. Estimates of dose from internally deposited Cs^{137} is quite tenuous. Reference Thirteen suggests the relationship:

10 millicuries of $Cs^{137}/mi^2/yr$ -----> 0.5 - 2.0 mrem year.

Shortly after the attack some 400 curies of cesium-137 per square mile (assuming no fractionation) would fall in the area under consideration. This is a somewhat different situation than the one upon which the above relationship was based, inasmuch as this is a single fallout (the Cs^{137} dribble from the stratosphere and troposphere would contribute relatively little). However, additional dosage will come as the cesium is being eliminated from the body after reaching equilibrium with the intake. Also, with such a heavy contamination in the environment as postulated here, there will be some re-suspension of the cesium after deposition on the ground.

As great, or greater, an uncertainty would be the contribution of the shorter lived isotopes present in the fallout. Time has not permitted an analysis of this factor. Whereas, the theoretical external gamma dose from shorter lived isotopes may be 2-1/2 times that of Cs^{137} (see page 27 for further discussion), their absorption into the body is much less. In addition there undoubtedly are other gross fission products that are absorbed into the body yielding a beta whole body dose.

H. Genetics(a)

Assume doubling dose $\longrightarrow$ 50 r (b) then,

A. Additional tangible defects

$$\frac{670^{(c)}}{50} \times \frac{1}{10} \times 2\% \xrightarrow{\sim} 2.7\%$$ or less(b) of all live births first generation(d)

B. Additional stillbirths and childhood deaths

2-1/2 times tangible defects(19)

$(2.5)\ (2.7\%) \xrightarrow{\sim} 6.7\%$ or less(b) of all pregnancies first generation(d)

C. Additional embryonic and neonatal deaths

5 times tangible defects(19)

$(5)\ (2.7\%) \xrightarrow{\sim} 14\%$ or less(b) of all conceptions first generation(d)

(a) The following estimates generally apply to relatively large populations and therefore would not be so appropriate to the more limited numbers of persons being considered here.

(b) Recent data from Dr. Russell (Oak Ridge) shows less production of genetic defects at lower dose rates by a factor of about four. The above estimates, therefore, may be high.

(c) Total genetic exposure.

(d) With decreasing effects in succeeding generations.

(e) Normal rates today -

2% (of all live births) - tangible defects
5% (of all pregnancies) - stillbirths and early childhood deaths
10% (of all conceptions) - embryonic and neonatal deaths

Carbon-14

1. Assume: 1 M.T. (total yield) $\dashrightarrow$ 2×10^{26} neutrons (Outside bomb)
$\dashrightarrow$ 4.7 Kg C^{14}

   If one-half of neutrons "lost" to ground (i.e. surface bursts),

   then $\dashrightarrow$ 2.4 kg. C^{14}/M.T.

2. 3953 M.T. (total yield) $\overset{\sim}{\dashrightarrow}$ 9.3×10^3 kg. C^{14}

3. There are two reservoirs for freshly produced C^{14}:(21)

   4.4% in reservoir A(a) with Tm of 8070 yrs.

   95.6% in reservoir A with Tm of 27.2 yrs.

4. There are 3200 kg. C^{14} normally present in reservoir A(b).

$$\frac{(9.3 \times 10^3)\ (4.4 \times 10^{-2})}{3200} \times 8070 \times 1.5^{(c)} = 1550 \text{ mr}$$

$$\frac{(9.3 \times 10^3)\ (9.6 \times 10^{-1})}{3200} \times 27.5 \times 1.5 = \underline{120 \text{ mr}}$$

$$\underline{\text{Total}} \quad 1670 \text{ mr or} \sim 1.7\text{r}$$

5. Assuming that transmutations account for roughly the same number of genetic defects as does radiation, (22) then: ~3.4 r "effective" over 8000 years.

6. During the same period of time (8000 years) the dose from naturally occurring radioisotopes in the environment and from cosmic rays might amount to 800 r (assuming no change in the present rate). The effect from C^{14} would not be zero but would not constitute a problem to the same degree as other factors.

(a) The atmosphere, the land biosphere, and humus.

(b) This assumes uniform distribution over the world which may not be too greatly in error for C^{14}.

(c) Yearly dose from C^{14} present in environment.

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Criteria for Establishing Short Term Permissible Ingestion of Fallout Material

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THE CRITERIA for establishing permissible ingestion of radioactive fallout material under emergency conditions for several weeks following a nuclear detonation are dependent primarily on exposures to the,

a. gastrointestinal tract from the gross fission product activity,

b. thyroid from the isotopes of iodine and,

c. bone, principally from Sr^{90}-Y^{90}, Sr^{89}, Ba^{140}-La^{140}.

I. Doses to the Gastrointestinal Tract

The following principal assumptions are used in calculating the doses to the gastrointestinal tract of adults:

a. The calculations are based on the methods contained in reference one.

b. The fallout material is 90 per cent insoluble. (See IV. Discussion below).

c. The activity decays according to the principle of $(\text{time})^{-1.2}$.

d. The energy delivered is all derived from the beta emissions, having a mean energy of 0.4 Mev when in the lower large intestine. (See Graph 1)[2]

e. The total daily consumption of food and water is 2200 grams or milliliters.

The method of calculation is according to the following equation:

$$\frac{(\text{Total number of disintegrations occurring in organ})\ (\text{Energy of emissions})\ (8.0 \times 10^{-9})}{\text{Mass of Organ}} = \text{Dose (rads)} \quad (1)^{*}$$

The number of disintegrations taking place in the organ may be calculated according to equation two:

$$\text{Total number of disintegrations} = 5A_a\ t_a^{1.2}[t_a^{-0.2} - t_b^{-0.2}] \quad (2)$$

Where: A_a = number of disintegrations per unit time at time "*a*" after detonation.

t_a = time "*a*" after detonation.

t_b = time "*b*" later than "*a*".

One of the more useful forms for the criteria would be in units of permissible concentrations at time of intake. This will somewhat complicate the calculations since there will be a decrease in activity as the material passes along the gastrointestinal tract. When such calculations are made according to the above assumptions and equations, it may be seen that the critical organ is the lower large intestine except for the first hours immediately following the detonation. (Table I shows the relative doses to parts of the gastrointestinal tract as a function of time.) Therefore, Graph 2 is based on the activity at time of ingestion to produce one rad of dose to the lower intestine.

For example, Graph 2 shows that if about 48 microcuries are ingested on the 24th hour after detonation, the lower large intestine may receive one rad of radiation dose. This was calculated in the following manner.

Step 1. Determine the total number of disintegrations in the lower large intestine necessary to produce 1.0 rad.

From equation (1)

$$\frac{(\text{Number of disintegrations})\ (0.4)\ 8.0 \times 10^{-9})}{150} = 1$$

Number of disintegrations $= 4.7 \times 10^{10}$

Step 2. Determine the activity at time of intake to produce 4.7×10^{10} disintegrations within the large intestine.

$$\frac{4.7 \times 10^{10}}{0.9} = 5.2 \times 10^{10}$$ disintegrations intake required (assuming 10% solubility).

From equation (2)

$$5.2 \times 10^{10} = (5)\ (A_{37})\ (37^{1.2})\ [37^{-0.2} - 55^{-0.2}]\ ^{*}$$

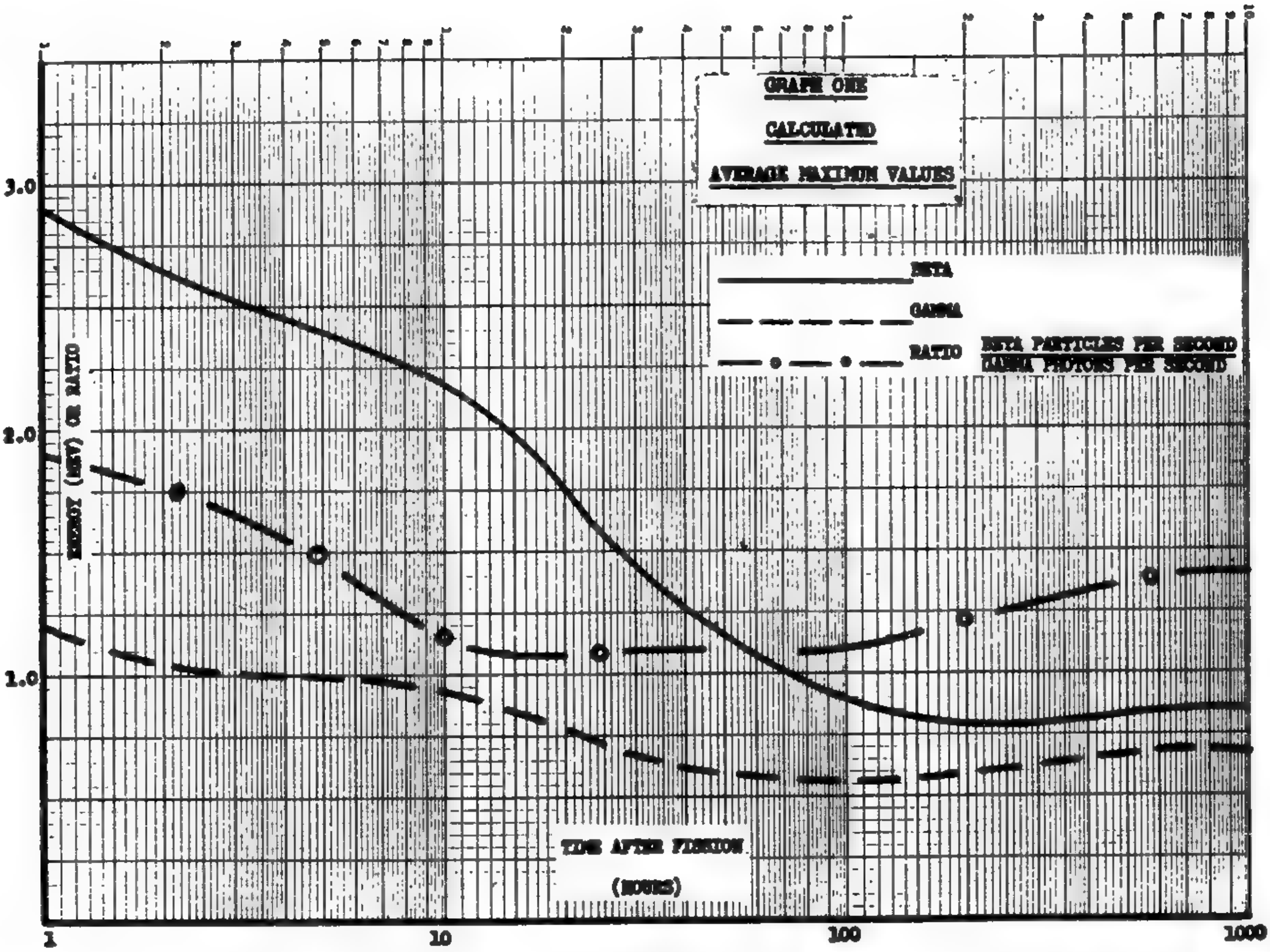
$A_{37} \cong 3.7 \times 10^{9}$ d/hr.
$A_{24} \cong 6.2 \times 10^{9}$ d/hr.
$A_{24} \cong 47\ \mu c$

---

* The rad is the unit of absorbed dose equal to 100 ergs per gram.

$$\frac{1.6 \times 10^{-6}\ (\text{ergs/Mev})0.5\ (\text{proportion of total energy to gastrointestinal tract})}{100\ (\text{ergs/gm-rad})} = 8.0 \times 10^{-9}$$

* If the time of intake is the 24th hour, then the start of irradiation of the lower intestine is 24 + 13 = 37th hour, according to reference one.



GRAPH 1

TABLE I

Relative Doses to Gastrointestinal Tract from Ingestion of Fallout Material

	Time After Detonation That Ingestion Occurs		
	1st Hour	1st Day	Limiting Case*
Lower Large Intestine	1.0	1.0	1.0
Upper Large Intestine	1.8	0.71	0.49
Small Intestine	0.26	0.054	0.03
Stomach	0.86	0.063	0.03

* Based on assumption that there is no significant decrease in activity during time of passage through gastrointestinal tract. After a week following detonation the decrease in activity between the stomach and the midpoint of time in lower large intestine is within about 20% of this condition.

Graph 2 has been used in estimating radiation doses to the lower large intestine for prolonged periods of ingestion (Table II). The following calculations are illustrative for the period of 24th to the 120th hour (start of intake at the beginning of the 2nd day after detonation for a duration of four days).

Step 1. Determine the number of microcuries at time of ingestion to produce 1.0 rad to the lower large intestine.

From Graph 2 take the mid point of intake period (72nd hour) → 31 μc. (This is obviously an approximation since the exact times of intake during the four-day period will be unknown.)

Step 2. Determine the activity at time of intake.

From equation (2)

$31 = 5A_{24}\ 24^{1.2}\ [24^{-0.2} - 120^{-0.2}]$

$A_{24} \cong 0.94\ \mu\text{c/hr}$

Since there is assumed a 2200 ml/day intake

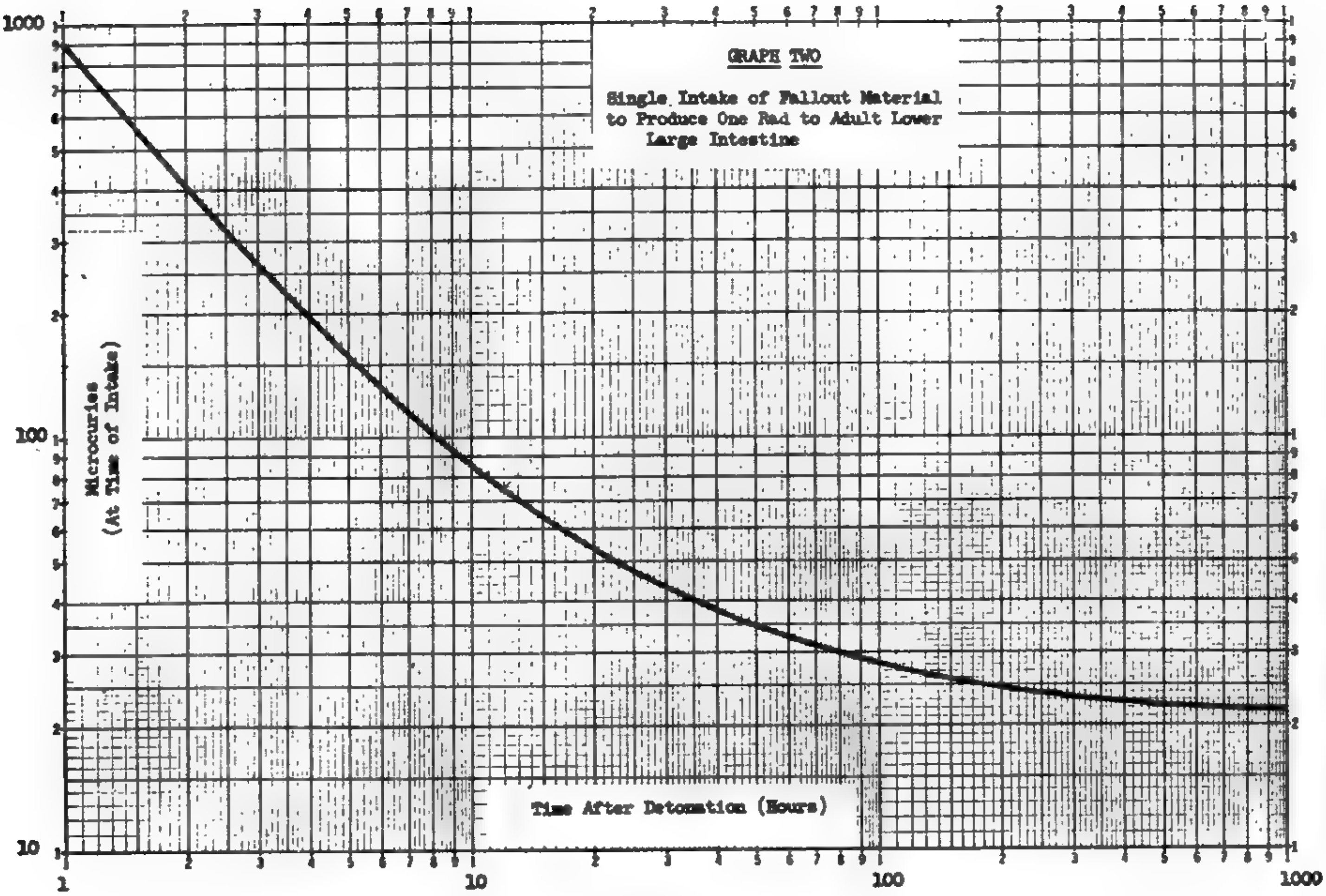
$$0.94 \times \frac{24}{2200} \cong 0.010\ \mu\text{c/ml or gm}$$

II. Doses to the Thyroid

The following principal assumptions are used in calculating the doses to the adult thyroid from intake of activity from fallout material:

a. The percentages of the isotopes of iodine in mixed fission products are according to Hunter and Ballou.[8]

b. Twenty percent of the ingested I^{131} reaches the thyroid.



GRAPH 2

c. The mean energy is 0.22 Mev.

d. The thyroid weight is 20 grams. (See IV. Discussion below)

e. The percentages of shorter-lived isotopes of iodine that reach the thyroid and their doses are according to reference four.

The method of calculation of doses to the thyroid is illustrated by computing that amount of intake of fission products at the 48th hour to produce 1.0 rad.

Step 1. Determine the dose rate on the day of intake of I^{131} to produce 1.0 rad to the thyroid.

$D = (R/\lambda_e)$

Where: D = dose (1.0 rad)
R = dose rate on initial day
λ_e = effective decay constant (radiological and biological)

$1.0 = (R/0.09)$

$R = 0.09$ rads/day

Step 2. Determine the number of microcuries of I^{131} to produce 0.09 rad/day

$$\frac{X(\mu c)(2.2 \times 10^6)(60 \times 24)(1.6 \times 10^{-6})(0.22)}{(100)(20)} = 0.09$$

$X = 0.16\ \mu c$ to thyroid or

$(0.16)\ (5) = 0.80\ \mu c\ I^{131}$ ingested

Step 3. Determine relative doses from I^{131} and I^{short} according to Graph 3.[4]

TABLE II

Approximate Fission Product Activities (Microcuries per Milliliter of Gram × 10^2) to Produce one Rad Dose to Lower Large Intestine*

Duration of Ingestion (Days)	Start of Intake (Days after detonation)							
	1 (1st Hour)	2 (24th Hour)	3	4	5	10	15	20
1	35	2.5	1.9	1.7	1.4	1.1	1.1	1.0
2	24	1.7	1.1	0.89	0.81	0.62	0.57	0.53
3	15	1.3	0.82	0.65	0.56	0.41	0.40	0.37
4	13	1.0	0.65	0.53	0.46	0.33	0.30	0.29
5	12	0.9	0.57	0.44	0.39	0.28	0.25	0.22
10	9.2	0.64	0.40	0.29	0.25	0.17	0.14	0.13
15	7.8	0.53	0.33	0.26	0.21	0.13	0.11	0.097
20	7.5	0.49	0.29	0.21	0.18	0.11	0.089	0.079

* a. Activities computed at start of intake period.

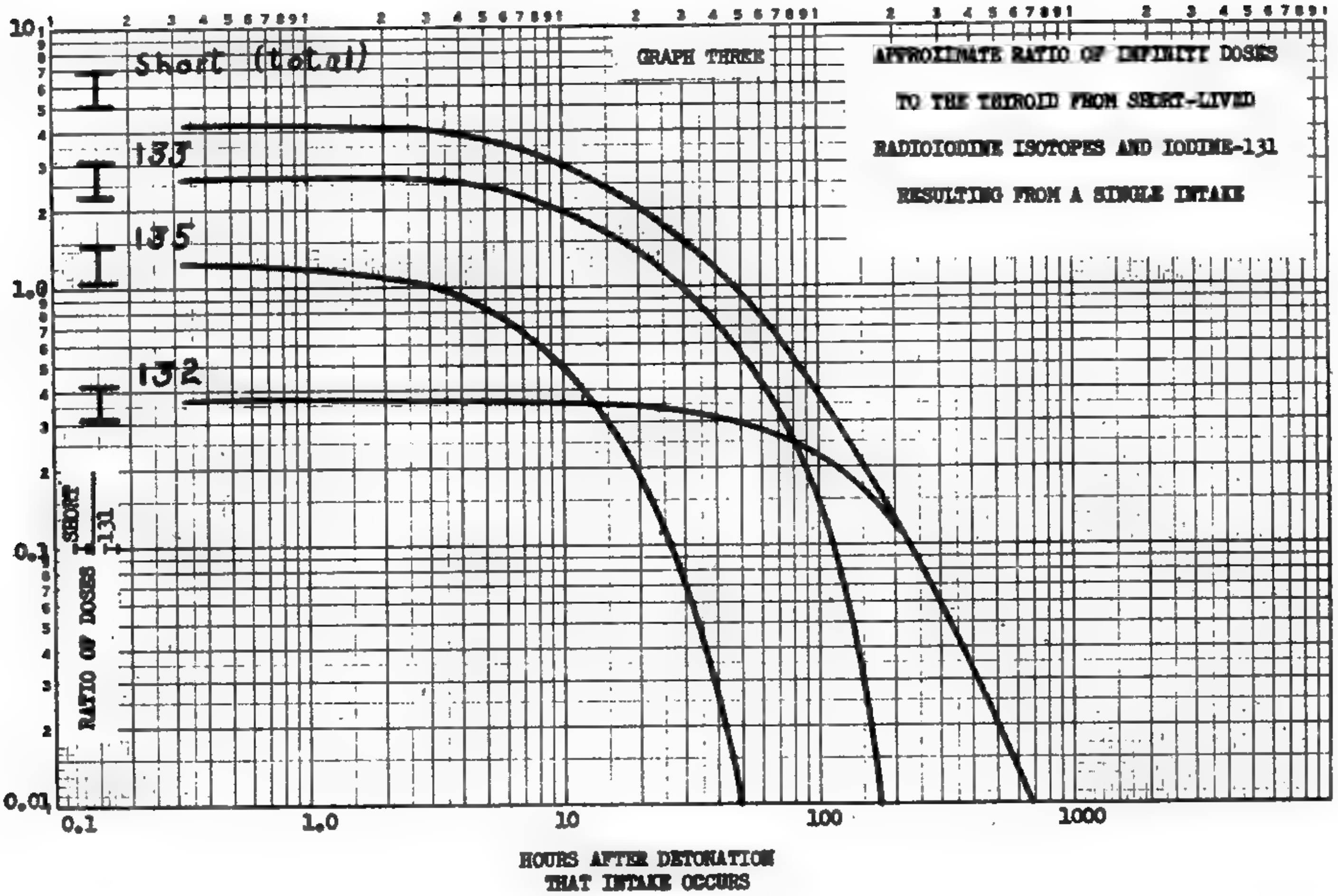
b. Based on intake of 2200 milliliters or grams of water and food per day for adults.

At 48th hour, the relative contribution to total dose from I^{131} and I^{short} is about 1/1.

Therefore, ingestion of $0.4\ \mu c\ I^{131}$ (equivalent) at 48th hour will produce 1.0 rads to thyroid.

Step 4. Determine the number of microcuries of fission products required to yield the required I^{131} activity. At 48th hour, I^{131} constitutes about 2.35% of total activity. Therefore,

$(0.4/0.023) \cong 17\ \mu c$ of fission products.



GRAPH 3

Graph 4 shows the number of microcuries of fission products ingested at times after detonation to produce 1.0 rad to the thyroid.

III. Doses to the Bones

The three principal bone-seeking isotopes of concern are Sr^{90}-Y^{90}, Sr^{89}, and Ba^{140}-La^{140}. Evaluation of these may be made in terms of amount deposited in the bones versus maximum permissible body burdens, or in rads of dose that they deliver after deposition. Since values for maximum permissible body burdens are based on the concept that these will be maintained indefinitely in the body, they are not so valid for Sr^{89} and Ba^{140}-La^{140} when considering short periods of emergency intake.

The following principal assumptions are used in calculating the doses to the bones of adults:

a. The percentages of the isotopes of Sr^{90}-Y^{90}, Sr^{89}, and Ba^{140}-La^{140} in mixed fission products are according to Hunter and Ballou.[3]

b. The percentages of intake of these isotopes that are deposited in the bones, the energies of emissions, and their effective half lives are according to reference five—except for Sr^{90} where a 27.7 year radiological half life is used here.

c. The mass of the bones is 7,000 grams.

The method of calculation of doses to the bones is illustrated by computing the dose from Sr^{89} from the intake of 27 microcuries (See IV Discussion below) of mixed fission products on the 120th hour. Similar calculations were made for Sr^{90}-Y^{90} and Ba^{140}-La^{140} and then the three doses were added for each intake of fallout material.

Step 1. Determine the Sr^{89} to reach the bone.

According to reference 4:

The Sr^{89} content in mixed fission products on the 120th hour is 1.6%.

According to reference 5:

The intake of Sr^{89} to reach to the bones is 25%.

Therefore:

(27) (0.016) (0.25) = 0.108, to the bone.

Step 2. Determine the dose rate to the bones.

With an assumed effective energy of 0.55 Mev (reference 5):

$$\frac{(0.108)(2.2 \times 10^{6})(60 \times 24)(1.6 \times 10^{6})(0.55)}{(100)(7{,}000)}$$

$$= 4.3 \times 10^{-4} \text{ rads/day } \textit{or } 0.43 \text{ millirads/day}$$

Step 3. Determine total dose.

D total = $(R/\lambda e)$

where: R = initial dose rate

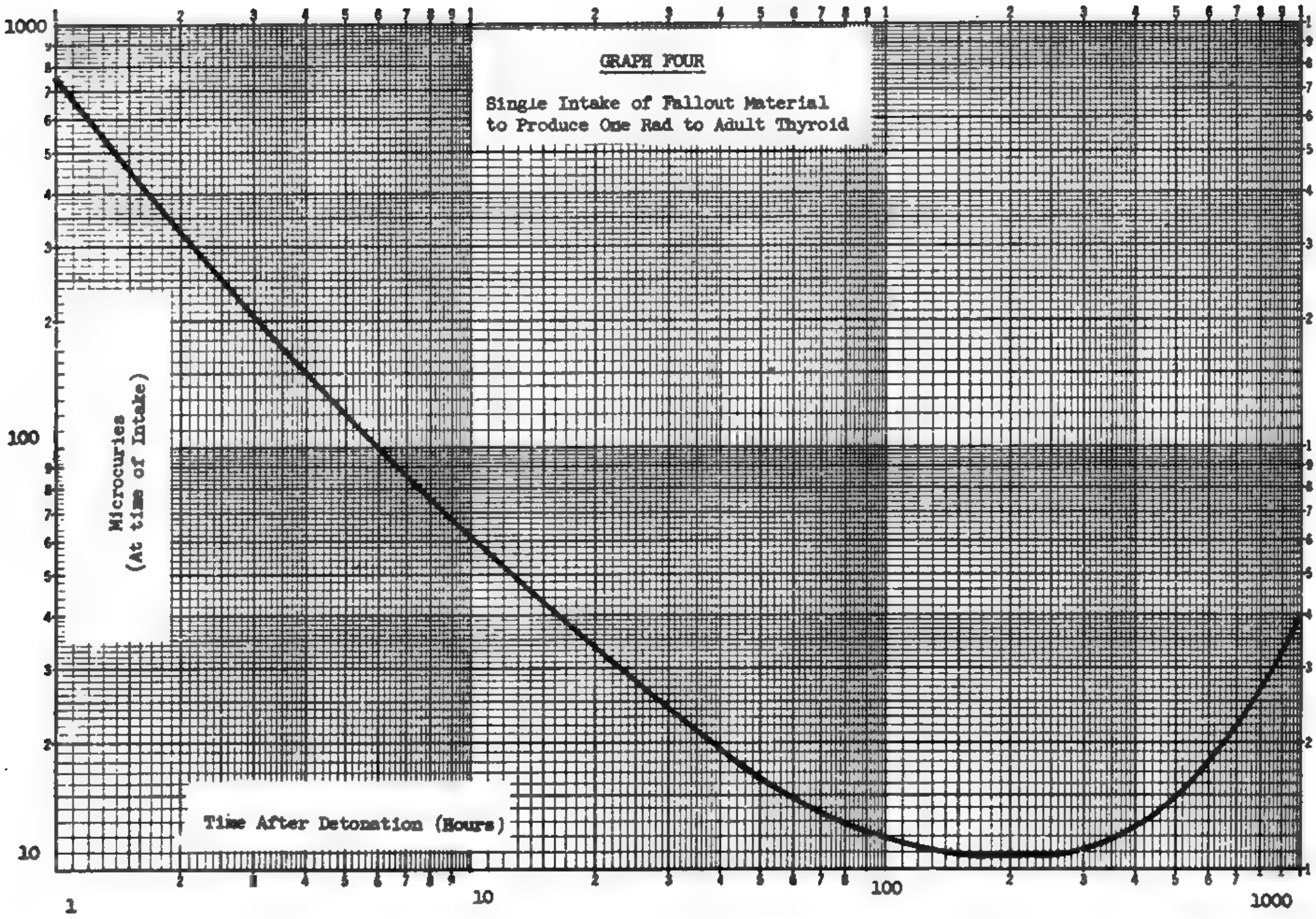
λe = effective decay constant

D total = (0.43/0.0133) ≅ 32 millirads*

---

* The relative total doses from these isotopes are as follows:

Time of intake	Sr^{90}	Sr^{89}	Ba^{140} — La^{140}
24th hour	0.6	1.00	0.6
20th day	1.00	1.00	0.3



GRAPH 4

IV. Discussion

A. SOLUBILITY

The solubility of fallout material varies, depending among other factors upon the surface over which the detonation occurred. The fallout material collected in soil samples at the Nevada Test Site has been quite insoluble, i.e. only a few per cent in distilled water and roughly 20–30 per cent in 0.1 N HCl. However, it would be expected that the activity actually present in drinking water supplies would be principally in soluble form. The water collected from a well and a cistern on the Island of Rongelap (Table III) about 21 months after the March 1, 1954 fallout, was found to have about 80 per cent of the activity in the filtrate, but there was an undetermined amount that settled to the bottom. Other data suggest the material to have been about 10–20 per cent soluble in water.

In the event contaminated food is ingested it is possible that the total activity—soluble and insoluble—may find its way into the gastrointestinal tract since at times immediately following a fallout most of this activity probably would come from the surface contamination rather than the soil-plant-animal cycle. There may then follow some solubilizing in the acid stomach with subsequent removal from the tract before reaching the lower large intestine.

TABLE III

Concentrations in Water on Islands in the Pacific and Estimated Gamma Dose Rates at D + 1, Three Feet Above Ground

Date	Location	Gross Fission Product Activity (*d*/*m*/ml)
	Rongelap Island (3.5 roentgens per hour)	
D + 2	Cistern	~50,000–75,000
D + 34	"	~5,500
D + 34	Openwell	~2,000
D + 300	Cistern	~3
D + 330	"	~4
D + 600	"	~5.5
D + 600	Openwell	~0.5
D + 600	Cistern (With collapsed roof)	~1.3
	Kabelle Island (19 roentgens per hour)	
D + 330	Ground water	~48
	Eniwetok Island (8.5 roentgens per hour)	
D + 330	Cistern	~25
	Enibuk Island (1.3 roentgens per hour)	
D + 600	Standing water from can, drum, etc.	~1.4

It is assumed for these calculations that (a) 90% of the fallout material is insoluble when computing doses to the gastrointestinal tract, and (b) that the isotopes of iodine, strontium, and barium are all soluble when computing doses to the thyroid and to the bones. These assumptions are probably conservative, i.e. they may overestimate somewhat the radiation exposures.

B. Biological Significance

After the estimation of radiation doses by any procedure the final step is an evaluation in terms of biological effects both for short and long terms.

1. Gastrointestinal Tract

There have been few experiments where the gastrointestinal tract has been exposed in a manner similar to the one assumed here. One experiment[6] indicates lower doses to the intestine than the model proposed in reference 1.

In another experiment,[7] rats were fed 1.0 to 6.0 millicuries of yttrium-90 in a single feeding. Four of the 33 animals died of adenocarcinoma of the colon and additional animals died with acute and chronic ulceration of the colon. A second group of rats was given 0.46, 0.20, or 0.06 mc of Y^{91} per feeding over a period of three months with total accumulated amounts of 31.2, 15.6 and 4.68 mc respectively. Six of the eight animals at the two higher levels died with carcinoma of the colon and no malignancies were observed at the lowest level. The authors made no estimate of radiation doses.

In another experiment,[8] rats were kept alive by the use of parabiosis or para-aminopropriophenone either pre or post whole-body irradiation of 700–1000 roentgens. Four of the 21 rats developed tumors along the gastrointestinal tract (one each jejunum, ileum, duodenum, and colon), with four additional animals showing tumors in other organs. However, in comparing gastrointestinal versus whole-body irradiation, the question has been raised as to a possible indirect carcinogenic action in the latter case.[9] By using fast neutrons, lesser doses have been shown to produce an appreciable percentage of intestinal carcinomas in mice, but this is not so relevant to the present discussion of beta exposure.[10]

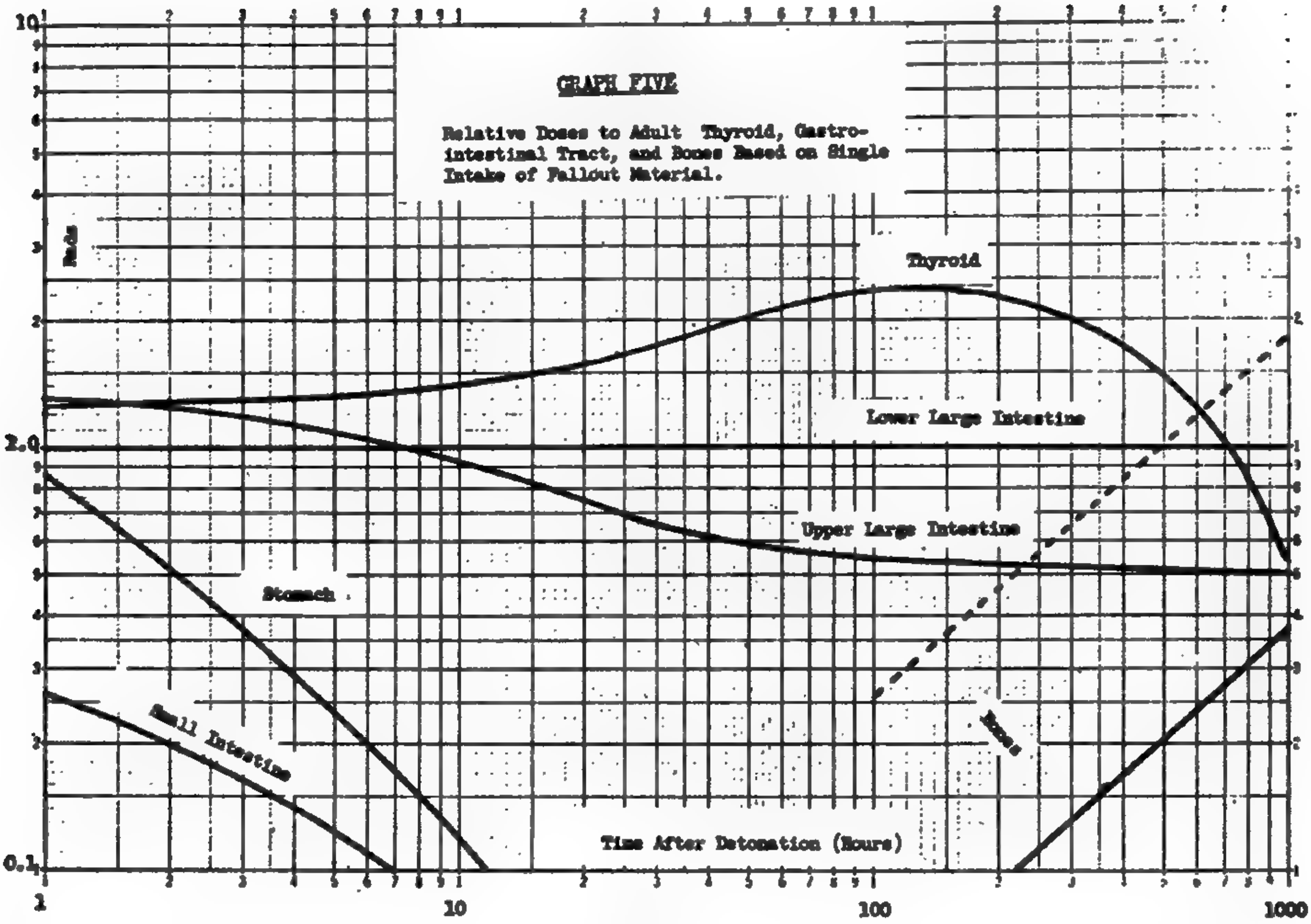
One summarizing statement of the short-term effects stated, "...though the gastrointestinal tract is one of the sensitive systems to ionizing radiation, it also has a most remarkable regenerative and reparative capacity. It takes doses of well over a thousand roentgens to damage the gut permanently in most mammals studied, and it is capable of rapid, dramatic recovery of anatomical and functional integrity with doses in the lethal range."[11] Evaluating the data from dogs exposed to whole-body X-radiation the authors said, "...it is suggested that doses of approximately 1,100 to 1,500 r may represent the upper limit of the possible efficacy of supportive measures in the treatment of the syndrome of acute radiation injury. With greater doses the damage to the intestinal mucosa appears irreparable and of an extent incompatible with life."[12] At the same time, it has been repeatedly indicated that the irradiation of the gastrointestinal tract plays a major role in gross whole-body effects associated with radiation syndrome.[11, 12, 13, 14, 15, 16, 17, 18, 19, 20] In fact one author[13] summarizes several experimental findings, "In producing acute intestinal radiation death, irradiation of any major portion of the exteriorized small intestine alone is almost equivalent to whole-body irradiation...."

Graph 5 suggests the relative doses to the parts of the gastrointestinal tract, from ingestion of fallout material. The available experimental data does not permit a conclusive statement as to whole-body effects to be expected from such ratios of exposures. Most of these experiments are related to the criterion of death, but they do suggest that the major contributory factor to such effects such as nausea and vomiting associated with whole-body exposures of 100–200 roentgens, may be the result of the gastrointestinal reaction. Possibly a few hundred rads to the lower large intestine together with the concomitant lesser exposures to the upper large intestine, the small intestine and the stomach (according to Graph 5) may be in the range where radiation sickness might occur.

2. Thyroid

The study and treatment of disorders of the thyroid gland with radioiodine has led to considerable information on doses and their effects to this organ. (Only a partial list of references is noted.)[21, 22, 23, 24, 25] Whereas these treatments have been principally with abnormal thyroids, much of the information may be extrapolated to normal thyroids for the purposes of this discussion. In addition there are other data based on normal thyroids in patients suffering such ailments as congestive heart failure.[26]

The picture clearly presented is that the adult human thyroid is relatively insensitive to radiation. For example, Freedberg, Kurland, and Herman,[26] report, "...Seven days after administration of 17 and 20 millicuries of I^{131}, which delivered 14,500 and 31,000 rep, respectively, to the thyroid gland, no histologic



GRAPH 5

changes were noted which could be attributed to I^{131}. . . . Fourteen and twenty-four days, respectively, after administration of 59 and 26 millicuries of I^{131}, marked central destruction of the thyroid gland was noted. . . ." Since the first two patients expired seven days after administration of the I^{131} from pulmonary edema, it does not eliminate the possibility that the destructive changes might have appeared in the thyroid if these patients had survived. However, the evidence from other studies strongly indicates that if any pathological effects were to be noted in the thyroid after an exposure of some 10,000 reps they would be minimal. Likewise, the possibility of serious damage to other organs of the body, such as parathyroids and trachea which are simultaneously exposed to the I^{131} radiations, would be exceedingly small.

On long terms effects, two summarizing statements may be made. "No thyroid neoplasm was found which could be attributed to I^{131},"[25] after doses to normal thyroids running into many tens of thousands of reps and after periods of observation up to more than eight hundred days. "In a series of over 400 patients treated with radioactive iodine at the Massachusetts General Hospital during the past ten years no known carcinoma of the thyroid attributable to this agent has developed. Definite answers to the question of carcinoma formation must await prolonged observation of treated patients."[26] Here the average treatment dose of I^{131} was 10 millicuries and of I^{130} 25 millicuries.

However, significantly lesser doses may be carcinogenic in children.[27] ". . . It has been suggested that the human thyroid is less radiosensitive than other tissues, such as bone, since after many years of treatment of Graves' disease with radioactive iodine, no cases of resulting carcinoma have been reported. The customary dosages of I^{131} in such cases yield at least 4000 rep to the gland. On the other hand, carcinoma of the thyroid found in children and young adults has almost invariably been preceded by x-ray treatment to the upper part of the body, in amounts such as to yield as little as 200 r to the infant thyroid. It has been estimated that less than 3 per cent of such treated cases yield carcinoma; nevertheless, the data suggest that 200 r is a potentially carcinogenic dose to the infant thyroid. While the possibility exists that the carcinogenic action may be an indirect, hormonal one, it must still be recognized that this, like leukemia, is an instance of significant carcinogenesis by less than 1000 rep. It seems likely that the infant thyroid is unduly susceptible, but that the adult thyroid is not. . . ."[28]

Table II indicates the amount of ingested fission product activity to produce one rad dose to the lower large intestine and Graph 5 shows the relative doses to the gastrointestinal tract and the thyroid. It may be seen that ingestion of a given activity on the fourth and fifth days may result in nearly two and one-half times the dose to the thyroid as to the lower large intestine. For a continuous consumption of fallout material from the first hour to the 30th day the ratio of doses is about 1.7.

3. Bones

It is recognized that the intake and deposition of strontium-89 and 90 are intimately associated with the calcium in the diet. Whereas it has been assumed here that a fixed percentage of the strontium intake is deposited in the bones (reference 5). It is realized that this method involves uncertainties, as would the necessary assumptions to generalize for a wide variety of calcium—strontium ratios and intakes to cover multiple categories. In situations where doses to the bones appear to be the critical criterion (such as later times after detonation than considered here), it would be necessary to make a more precise evaluation.

Unequal distribution of isotopes in the bones has been observed. Thus, the dotted line in Graph 5 is included to suggest a possible larger dose to those regions.

Considerable data have been collected on radiation produced bone cancers. One summarizing statement that places this in proper perspective with the other factors discussed above is ". . . Visible changes in the skeleton have been reported only after hundreds of rep were accumulated and tumors only after 1,500 or more."[29] When one examines Graph 5 for relative doses, and reviews the data on doses versus effects to the gastrointestinal tract and possibly children's thyroids (Table IV), it would appear that exposure to the bones is not the critical factor for ingestion of fallout material under emergency conditions, for the first few weeks after detonation.

TABLE IV

Some Possible Biological Effects from Radiation Doses to Specific Organs*

Dose (Rads)	Gastrointestinal Tract	Thyroid	Bones
10,000		Minor changes in structure	
	Serious damage —survival threatened		Tumor production.
1,000	Tumor Production		
	Immediate effects such as nausea	Potential carcinogenic dose to few percent of children	Minor changes in structure
100			

* Lesser short term effects would be expected from the same doses distributed in time.

4. Summary of Biological Effects

Table IV summarizes some possible biological effects from radiation exposures. Due to inherent uncertainties in such analyses together with expected wide biological variances among individuals, Table IV is intended only to suggest a generalized picture of doses versus effects.

The physical calculations of radiation doses made above were for adults. For equal intakes of radioactivity, children probably would receive higher exposures due to the smaller organ masses, and in the case of bones a greater deposition would be expected. Also, there is the possibility of tumor production in the thyroids of some children at relatively low radiation exposures. It would appear wise therefore to establish lower limits of intake of radioactivity for children.

C. PERMISSIBLE INTAKE

The preceding discussion attempts to give estimates of radiation doses resulting from intake of fallout material, together with some possible biological effects. How much intake is actually permitted depends upon many factors including the essentialness of the food and water to sustaining life, and one's philosophy of acceptable biological risks and damage in the face of other possible hazards such as mass evacuation. Table II and Graph 5 give estimates of the amount of contamination in food and water to produce certain radiation doses to the critical organs. Table IV indicates possible biological effects from given doses. Using these references, command decisions may be made as to permitted intake of radioactivity.

Such evaluations as attempted here are necessary and valuable for planning purposes, but once the fallout occurs the emergency of the situation may preclude immediate analysis of the food and water supplies. Further, abstaining from ingestion of food and water because it

TABLE V

Mean Body Burden of Rongelapese

Radioisotopes	Estimated Activity at One Day (μc)
Sr^{89}	1.6–22
Ba^{140}	0.34–2.7
Rare earth group	1.2
I^{131} (in thyroid)	6.4–11.2
Ru^{103}	0.013
Ca^{45}	0.019
Fissile material	0.016 (μgm)

might be contaminated could not be continued indefinitely. Therefore, the following three common-sense rules are suggested:

1. Reduce the use of contaminated food and water to bare minimum until adequate monitoring can be done; use first any stored clear water and canned or covered foods; wash and scrub any contaminated foods and;
2. If the effects of lack of food and water become acute, then use whatever is available but in as limited quantities as possible. Whenever possible select what seems to be the least likely contaminated water and/or foodstuffs; and
3. Since it is especially desirable to restrict the intake of radioactivity in children, give them first preference for food and water having the lowest degree of contamination.

In an area of heavy fallout one matter to consider is the relative hazards from the external gamma exposure versus internal doses from ingestion of the material. (Inhalation is thought to contribute only relative minor doses under the conditions discussed here). The best evidence on this point is the fallout that occurred on the Rongelapese in March 1954. Those in the highest exposure group received 175 r whole-body external gamma exposure yet their body burdens of internal emitters were relatively low (Table V).[80] These and other data suggest that:

If the degree of contamination of an area is such that the external gamma exposure would permit normal and continuous occupancy after a fallout, the internal hazard would not deny it.

This is based on such reasonable assumptions of (a) about 50% reduction of gamma exposure from out-of-doors doses afforded by living a part of each day in normal family dwellings, (b) washing and/or scrubbing contaminated foods, and (c) excluding areas where relatively little fallout occurred, but into which may be transported highly contaminated food and/or water. After longer periods of time during which the gamma dose rates in an originally highly contaminated area have decreased to acceptable levels, it probably would be necessary to evaluate the residual contamination for the bone seeking radioisotopes, especially strontium-90.

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Representative **Holifield**. Dr. Stanton H. Cohn will present testimony on the evaluation of the hazards from inhaled radioactive fallout. Dr. Cohn is presently with the Medical Physics Division, Medical Research Center, Brookhaven National Laboratory. He is a member of the Subcommittee on Inhalation Hazards of the Pathological Effects of the Atomic Energy Radiation Committee of the National Academy of Sciences. He was a member of the U.S. Naval Medical Team which provided emergency medical treatment to the Marshallese accidentally exposed to fallout from operations in 1954. He studied the internal radioactive contamination of the exposed Marshallese. He was also a member of the AEC medical team which made the 5-year medical survey of the Marshall Islands in 1959 and studied the internal radioactive contamination by measuring body burdens of various fission products of 250 Marshallese using a whole body gamma scintillation counter. He participated in the direction of the study of the residual contamination of plants and animals of the Marshall Islands in two surveys in 1955 and 1956.

Dr. Cohn, we are happy to have you before us today and you may now proceed.

TESTIMONY OF DR. STANTON COHN,[1] BROOKHAVEN NATIONAL LABORATORY

Dr. **Cohn**. An individual exposed to an atmosphere contaminated with airborne radioactive particles will be subjected to both external and internal radiation. This contaminated atmosphere, which would most likely be an area of local fallout produced by a nuclear detonation, would subject the individual to penetrating gamma and superficial beta radiation from the exterior. Particles which become internalized as a result of inhalation and/or ingestion would subject the internal tisues and organs primarily to beta radiation, and to a lesser extent, to gamma radiation. Unconsumed fissile material may, in addition, supply internal alpha radiation.

It is difficult to determine the exact degree to which radiation from external and internal sources contribute to the total radiation an individual receives. It is even more difficult, and in fact, rather arbitrary (as will be shown later) to separate the contributions deriv-

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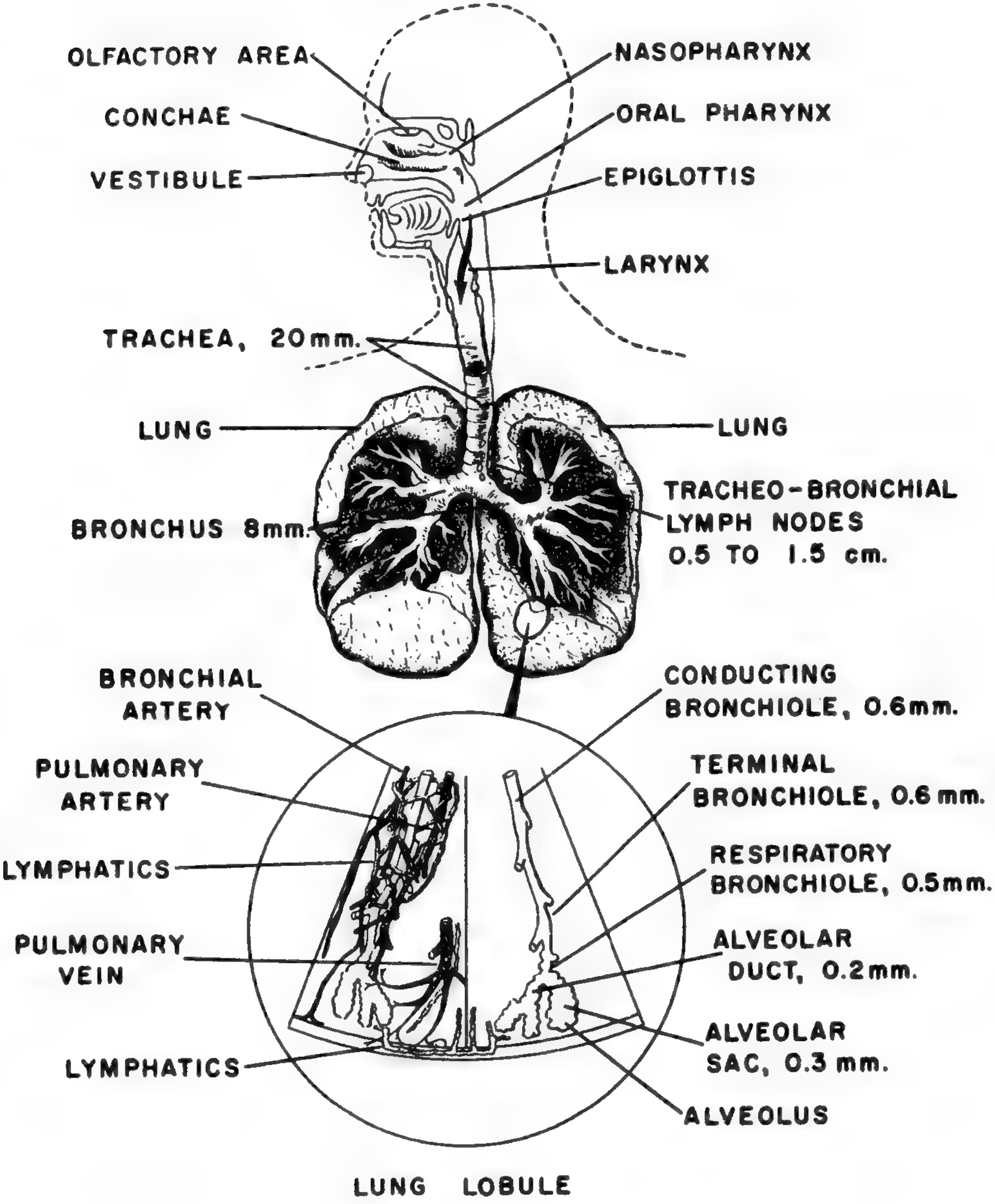
IV. Scientific Societies, memberships: Radiation Research Society, American Physiological Society.

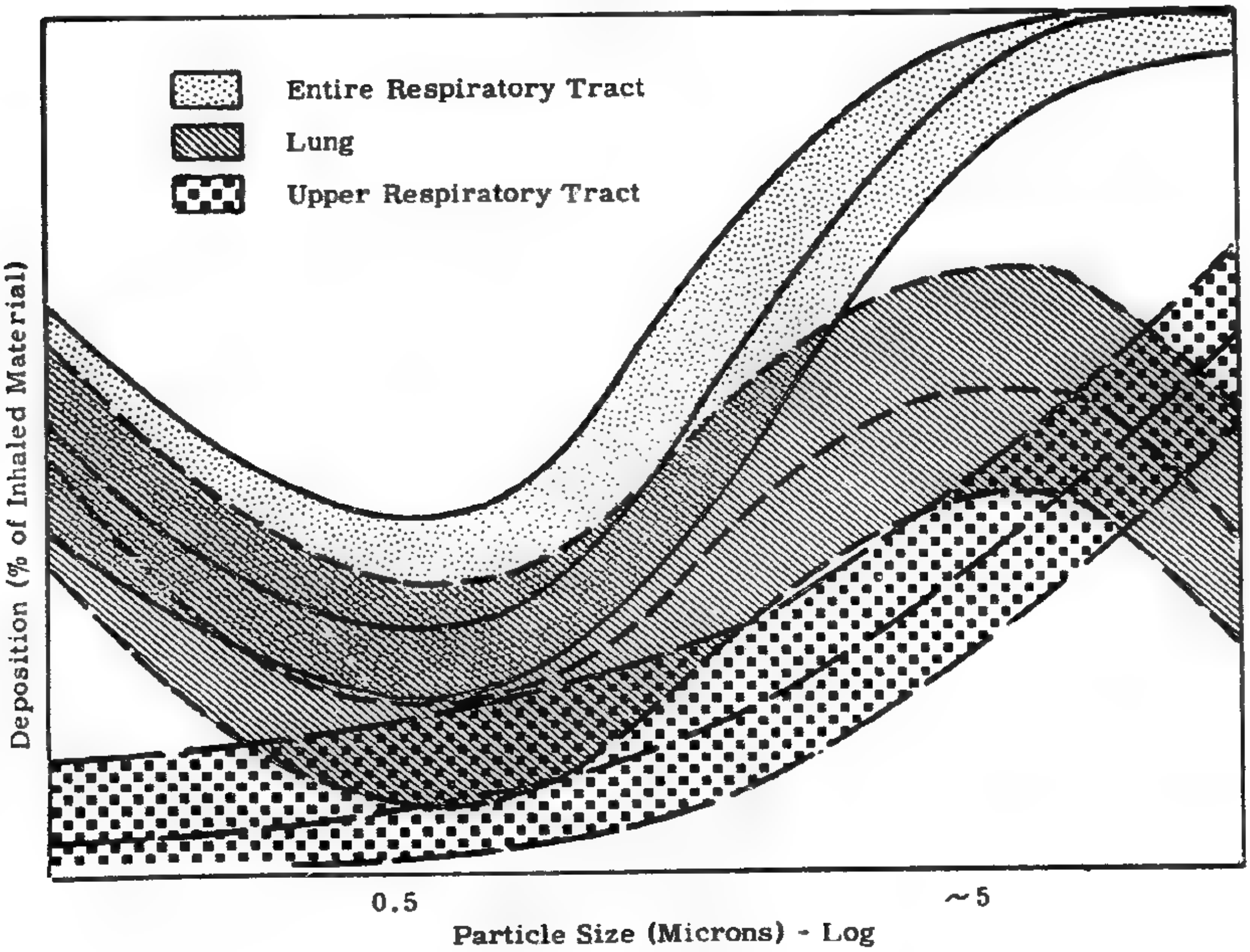
THE RESPIRATORY TRACT



When inhaled fallout material enters the respiratory tract, a fraction of the material is retained. Some of this material is subsequently removed, but a portion may remain for an appreciable period. Probably the most important property of fallout which influences the fate of the particles in the respiratory system is the size of the particle.

Both experimental and theoretical data on the deposition of particles with respect to particle size are summarized in figure 2. For decreasing particle size, as would be expected, deposition occurs deepest in the lung. With the increasing particle sizes, deposition occurs in the higher areas of the respiratory tract. A minimum in lung deposition occurs at 0.5 micron, and a maximum at 5 microns. Particles larger than 5 microns are retained by the upper respiratory tract and do not reach the lung. The nasal air passage acts as a trap or filter for these larger particles.

FIGURE 2



Deposition in Respiratory Tract

The rates of clearance of material from the respiratory tract are also important because they influence the tissue exposure time and thus determine the degree of radiation hazard to the lungs. The clearance of material from the lungs has not as yet been clearly delineated. However, it is thought that three mechanisms play a role in the removal of particulate material. These are ciliary action, transfer of soluble material across the alveolar membrane and phagocytosis. The action of ciliated epithelium in combination with mucous secretion results in a rapid "escalatorlike" upward movement of material deposited in the respiratory tract above the terminal bronchioles. Materials in the ciliated upper portion of the respiratory tract are removed to the G.I. tract within hours, or at most, a few days. Ciliary action is a continuous process and accounts for the removal of the largest fraction of particles from the respiratory tract.

Relatively soluble material is transferred across the alveolar membrane into the bloodstream, and thus enters the circulation in minutes, or at the most, a few hours. The material appears equally rapidly in the organ of ultimate deposition. The radiation dose to the lungs from such soluble material is much less than that received by the organ of ultimate deposition, which is usually the skeleton, because of the brief transit time in the lungs.

To a limited extent, the so-called insoluble materials are also absorbed through the lung and the G.I. tract.

The third method for removal of particulate material from the lung is phagocytosis, that is, engulfment of a particle by a phagocytic cell. A phagocytized particle may be moved into an alveolus and transported upward, or the phagocyte may enter the lymphatic circulation and be transported to the lymph nodes.

To provide a basis for estimating the accumulation of the many types of radioactive material in the lung in situations where actual data are not available, the International Committee on Radiation Protection (ICRP) has derived a model to describe general respiratory characteristics of deposition and clearance, as shown in figure 3. The total deposition of (50 percent plus 25 percent) or 75 percent for readily soluble compounds is conservative for most size ranges. The figure is 25 percent for deposition in the lung is based on animal studies, and may vary widely. For insoluble material, in addition to the 50 percent which is removed from the upper respiratory tract and swallowed, an additional 12.5 percent is removed from the deeper portions of the lung by ciliary action and swallowed.

The overall elimination rate of fission products from the lung can be described by a series of exponential functions (rate proportional to level), and over a longer period of time by a power function (rate of removal decreases geometrically with time). These rate values are needed to provide meaningful calculations of radiation dose.

FIGURE 3

Distribution of particulates in respiratory tract

Distribution	Readily soluble compounds	Other compounds
	Percent	*Percent*
Exhaled	25	25
Deposited in upper respiratory passages and subsequently swallowed	50	50
Deposited in the lungs (lower respiratory passages)	[1] 25	[2] 25

[1] This is taken up into the body.

[2] Of this, half is eliminated from the lungs and swallowed in the first 24 hours, making a total of 62.5 percent swallowed. The remaining 12.5 percent is retained in the lungs with a half-life of 120 days, it being assumed that this portion is taken up into body fluids.

It can be seen from the preceding discussion that the body has certain natural defenses against inhalation of fallout. First, the nasal passages and lungs act as a filter against large particles. Secondly, the alveolar and G.I. tract membranes filter on the basis of solubility.

Finally, much of the material which gains entry into the lungs is transferred to the intestinal tract where it is lost through normal elimination. In addition to these physiological protective factors, many of the fallout fission products produced have very short radioactive half-lives.

Very few data exist correlating a given amount of an internal emitter and a specific pathological response. Information on pathological injury to the lungs of human beings is derived largely from data on the effect of external radiation in the treatment of cancer of the breast and intrathoracic neoplasms. Two main types of lesions are formed, radiation pneumonitis and radiation fibrosis, representing different types of damage to the alveolar cells and wall. While individual variation in response to radiation are very large, there is a definite correlattion of the frequency of the above lesions with external dose.

Clinical experience on the effects of radioactive material deposited in the lungs is derived primarily from miners who were exposed for long periods to radium dusts and radon gas in mines. The best known cases of lung cancer caused by radium are those that occurred in the miners of Joachimsthal and Schneeberg in Czechoslovakia. While an increase in the occurrence of lung caner of the order of 50 percent was observed as compared with the general population, the etiology of the cancer is linked only circumstantially to the radium.

Other date on the pathological effects of radiation to lung are meager, and are based in part on experience with individuals exposed accidentally to radiation or radioactive materials or to high doses of therapeutic radiation. In accidental cases, the radiation dose received is most often unobtainable. Data on the late effects resulting from radiation therapy are very scarce, as frequently the followup on such effects is not made, and further, the study requires difficult statistical analysis.

The best source of data is the study of radiation effects on laboratory animals. From animal experimentation it is concluded that lung as a tissue has only moderate radiosensitivity. Damage is observed in lung tissue only after a large acute dose or repeated smaller doses of external radiation.

There is no question that radiation from internal sources can produce lung cancer, but it is not as yet possible to equate the changes produced with given levels of radiation dose. The best estimate of the external dose required to produce pulmonary fibrosis and pneumonitis lies in the range of 800 to 2000 rads, with a mean dose of about 1,000 rads. The induction of pulmonary cancer from radioactive material in experimental animals requires a dose of about the same order. The smallest dose to the lung which produced malignant tumors in mice was reported as 115 rad, following administration of 0.003 μc $Pu^{239}O_2$, and 300 rads after administration of 0.15 μc $Ru^{106}O_2$. However, other studies with mice have indicated that 2,000 rad was the threshold dose for lung tumor formation. Actually, almost all of these studies utilize intra-tracheal administration of the material for experimental ease. It is difficult to compare such an exposure to one deriving from true inhalation.

FIGURE 6

Internal radioactive contamination of Marshallese pigs exposed to fallout from the Mar. 1, 1954, nuclear detonation[1]

	Beta activity d/m/total sample $\times 10^{-3}$			
	Gross activity	Sr^{89}	Ba^{140}	Rare earths
Skeleton	8,745	5,380	595	850
(Total, percent)	(100)	(62)	(6.8)	(9.7)
Lungs (alveolar)	1.3	0.24	0.22	0.57
Stomach	1.6	0.26	0.62	0.80
Small intestine	2.5	0.73	0.69	0.69
Large intestine	14	5.0	2.8	4.0
Liver	29	0.47	0.27	5.9
Kidney	3.2	0.18	0.30	0.61
Remaining carcass	455			

Thyroid dose	100–150 rep—(estimated from early analysis of urine).
Total external gamma dose	330 r.
Internal beta activity	4 μc.

[1] These values are the average of 2 young adult pigs which were analyzed 3 months after detonation.

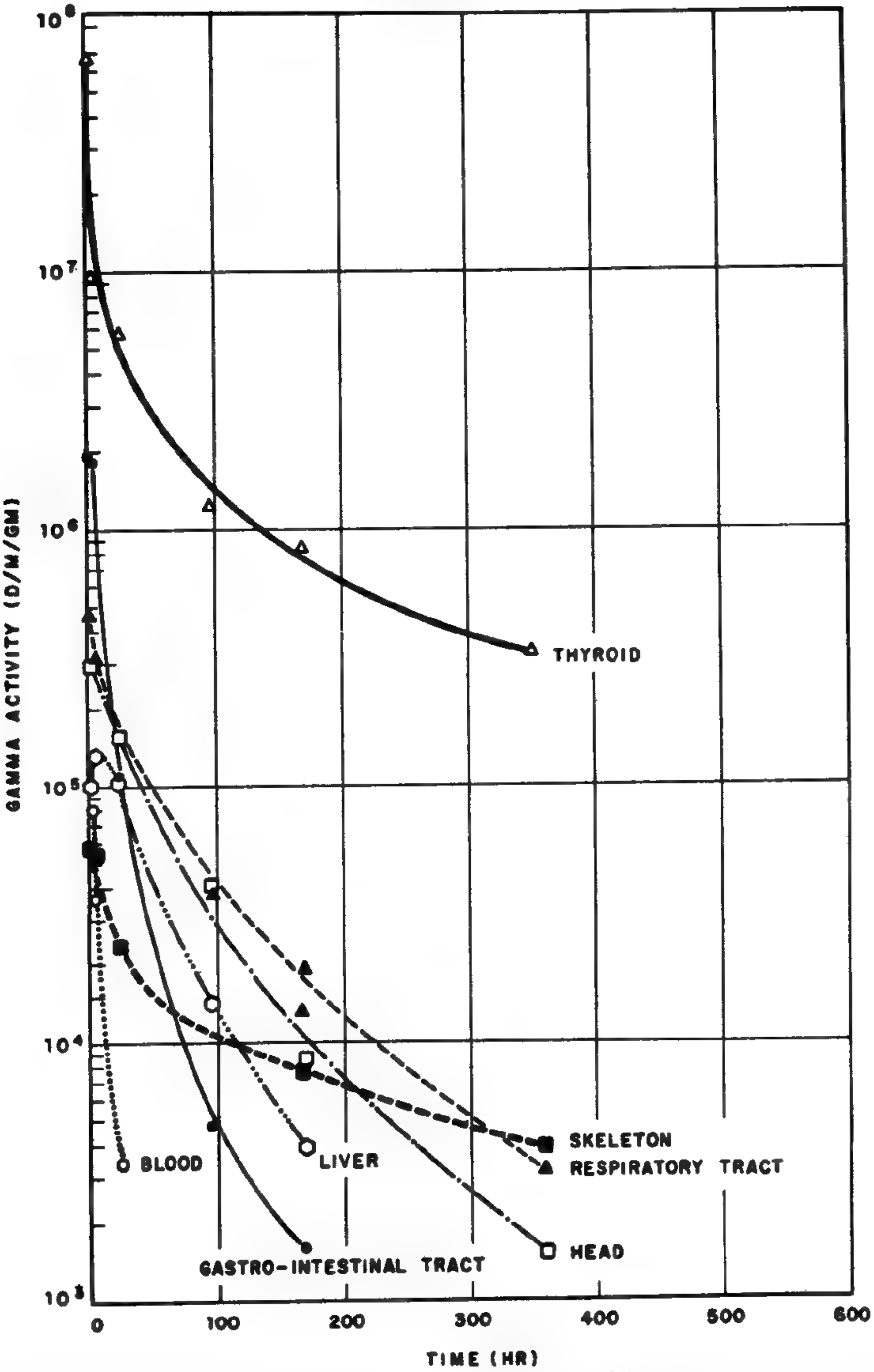
It can be seen that I^{131} and the shorter-lived I^{132}, I^{133}, and I^{135} contribute the highest individual tissue dose (100–150 rep to the thyroid). Although this is a large dose, studies with sheep indicate that doses of 16,000 r. are required to produce minimal changes in cell structure, and 50,000 r. are required to produce definite acute cell damage and hypothyroidism. Of the remaining fission products, Sr^{89} contributed the major portion of the beta dose to the skeleton. Thus the contribution of the total internal contamination in the Marshallese was small as compared to the 175 r. external gamma dose which they received.

In laboratory experiments designed to reproduce exposure to early fallout from various types of nuclear detonation, products from 2-day-old neutron bombarded uranium associated with various types of carriers were employed as fallout simulants.

In these inhalation experiments mice received an acute exposure from many of the short-lived radioisotopes not previously studied. The distribution, retention, and clearance of the fission products in these animals confirm the fact that the uptake and metabolism of the inhaled radioactive particles depend largely on the physical and chemical characteristics of the carrier material. The internally deposited radioactivity in the lungs, as well as in the skeleton and soft tissues (as shown in figure 7) decayed rapidly because the activity of the aerosol was contributed chiefly by short-lived radioisotopes and the biological loss of material from the lungs and soft tissues was very rapid.

While, as mentioned previously, the calculation of the internal radiation dose from fallout with any degree of precision is difficult, a rough approximation based on the experimental data here is feasible. To evaluate dose to individual tissues following this acute inhalation exposure, the activity per gm tissue as a function of time was determined. The greatest activity per gm tissue was observed in the thyroid at 1 hour following exposure. The total dose received by each organ for comparable energies is proportional to the area under its curve.

FIGURE 7



FROM: STANTON H. COHN, "RADIOTOXICITY RESULTING FROM EXPOSURE TO FALLOUT SIMULANT," REPORT USNRDL—TR—118 (1957), FIG. 5.

UPTAKE & RETENTION BY MICE OF A SIMULANT OF FALLOUT

PRODUCED BY A LAND BASED NUCLEAR DETONATION.

(MICE WERE EXPOSED TO 2-DAY OLD FALLOUT.)

RADIOLOGICAL HAZARD EVALUATION - A CRITICAL REVIEW OF PRESENT CONCEPTS AND A NEW APPROACH THERETO

by

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In the older approach, discussed in the previous section, the same basic set of effects data was applied in all of the above three situations. As the problems are more or less unique for each category some flexibility might be gained by altering the judgement criteria for the needs of the system.

GENERAL BASIS FOR APPROACH

Before making this subdivision it is probably worthwhile to first state a more or less unified concept of hazard and then adapt it to each situation.

When an individual is exposed to mixed ionizing radiations two specific organ systems are conceivably affected to an extent capable of causing either death or incapacitation. These organ systems are the bone-marrow-intestinal complex which may suffer physiological failure from the result of penetrating ionizing radiation; and the skin which can, as the result of the loss of its integrity, cause death or severe incapacitation. The latter organ can respond to radiation of all energies which penetrate to effective depths in the epithelium. If these are designated respectively deep effect and surface effect it is possible then to organize our thinking on the basis of two response criteria, one associated with the deep effect and one associated with surface effect. We shall refer to these as "deep hazard" and "surface hazard". They can be treated more or less independently in terms of acute effects as long as either one is relatively large with respect to the other. Data have been developed to show that the response to penetrating ionizing radiation is not detectably altered by superficial radiation as long as severe skin damage is not present.[13] In the presence of severe skin damage, on the other hand, it has been shown by Alpen, et al[15] and Brooks and Evans[14] that thermal burns of thirty percent or more of the body area reduce the X-ray LD_{50} appreciably.[14,15] Except for this limiting case we shall consider the two effects to be independent. When this assumption is made, an instrumental requirement is established for a detection device capable of assessing deep hazard independent of energy of the radiation

(SYNERGISM OF THERMAL BURNS
AND DEPRESSED WHITE BLOOD
CELL COUNT DUE TO RADIATION)

THE DEEP HAZARD

In Figure 3 is shown the relationship between the energy of the ionizing radiation and the dose effective in producing lethality in dogs. The data are for bilateral exposure to X-ray sources with rather broad energy bands, but it is reasonable to assume that only minor readjustments would need be made for more restricted energy limits. From the relative body and bone dimensions of dog and man it is possible to derive a curve of energy vs. effectiveness for lethality in man. This curve is also shown in the same figure. For estimation of hazard the instrument used in measuring dose, either portable radiac, pocket dosimeters or film badges should have a sensitivity which is reciprocal to this curve. We might state the requirement as follows. The instrument must have unit sensitivity for gamma radiation above approximately 80 KEV. At 30 KEV the sensitivity must be reduced to 50% of the maximum and it must detect no more than 1% of the gamma radiation of 15 KEV or less.

The principal basis for this requirement is the need to appropriately weigh whatever small amount of low energy gamma radiation is present, and, of much greater importance, to insure that none of the beta radiation present in the same environment is measured.

It has been mentioned in preceding sections that when radiation is from an extended plane surface or a ring type source that on the purely physical basis of depth dose enhancement the radiation will be 20 to 30% more effective than unilateral radiation at the same total dose. With this consideration in mind it is necessary to adjust the dose levels which will be predicted to yield a given response and also to require a geometrical responsiveness within the instrument that yields equal meter deflection for radiation from any angle. It has been shown that existing instrumentation is seriously deficient in this latter regard. Work[11] has shown that the shielding of the detector provided by the instrument case and the operator leads to a drop in detection sensitivity in the rearward quadrant. It seems that one of the more pressing requirements in radiac development at this time is correction of this deficiency.

Assuming that the requirements of energy and geometrical dependency of sensitivity are met in the detector, it remains for us to establish a series of standards of biological response that might be useful in implementing the three problems outlined in the previous section.

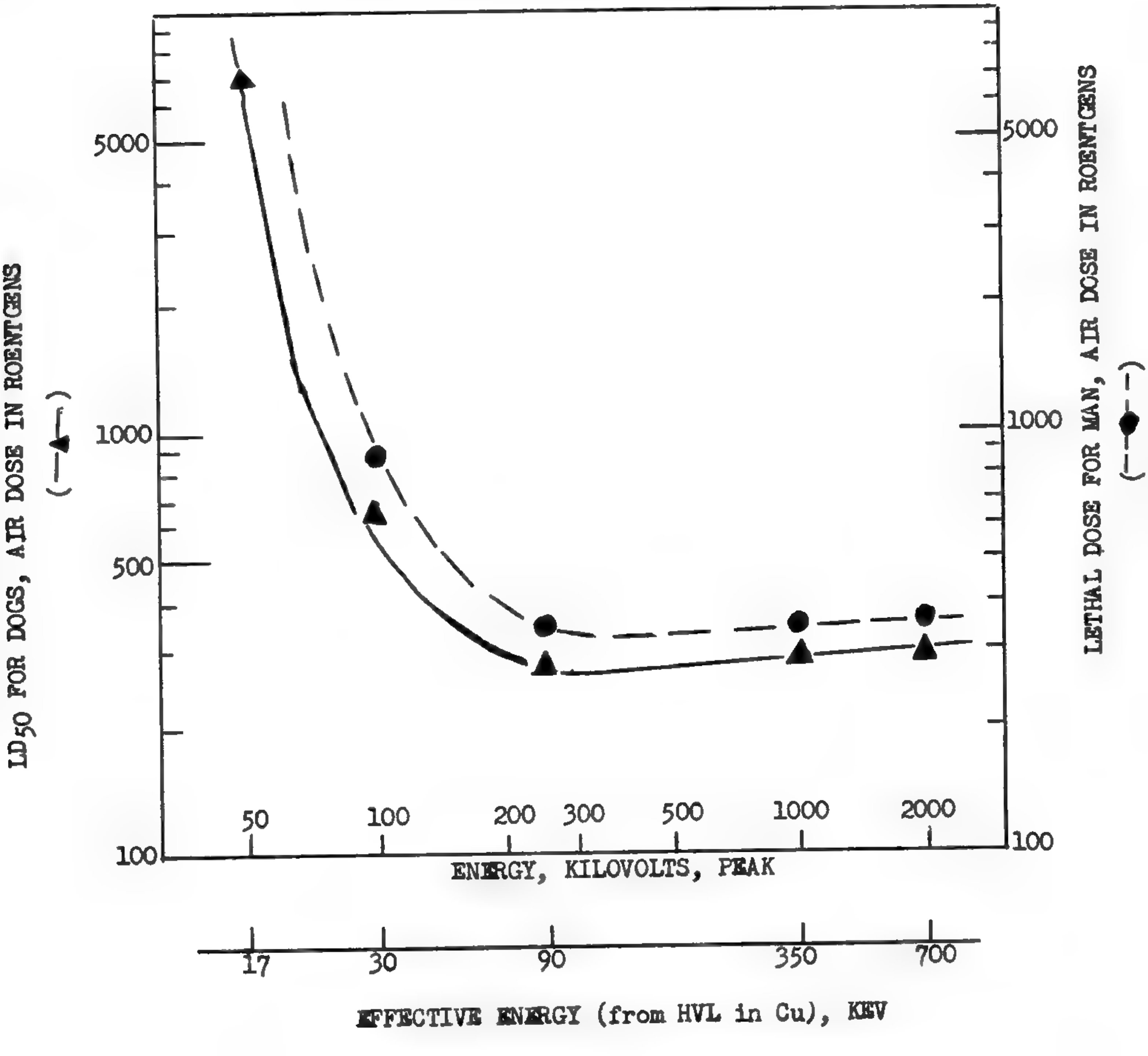

Fig. 3 Lethality of Ionizing Radiation as Related to Energy.

Solid line connects measured values of the LD_{50} for dogs, bilateral radiation. The dotted line connects the estimated values for man assuming a phantom thickness of 27 cm and an average bone thickness for marrow shielding of twice the value which would be found in the dog.

Given the data presented in Table 3 it is possible to construct an operational table similar to that formulated for deep hazard. Again it is possible to divide the dose range into two regions using the same criteria as were applied for the deep hazard. If severe erythema is accepted as the acute effect which will incapacitate, then a dose of 600 rad is set as the upper limit for operation based upon the criteria of maximum acceptable acute effects. The same reasoning holds as for the 9-150 r region of deep effects. Hazard is linearly proportional to accumulated dose up to this maximum figure. For doses over 600 rad the following table should be applied in accepting or rejecting maximum exposure levels.

Table 4

ACUTE EFFECTS OF IONIZING RADIATION ON SKIN

Estimated Dose Required (EDR) in $<$ 1 week	Effect
0-600 rad	No acute effects.
600-2000 rad	Moderate early erythema.
2000-4000 rad	Early erythema under 24 hours. Skin breakdown in 2 weeks.
4000-10,000 rad	Severe erythema in $<$ 24 hours. Severe skin breakdown in 1-2 weeks.
10,000-30,000 rad	Severe erythema in $<$ 4 hours. Severe skin breakdown in 1-2 weeks.
30-100,000 rad	Immediate skin blistering (less than 1 day).

Modifying Factors

Recovery rates for skin are as yet not extensively determined but one published report on rat skin[20] indicates that recovery is probably more rapid for skin than for deep effects. No information is available as to permanent non-recoverable fraction. As a rule of thumb it is probable that a factor of 2 could be applied to the above tabulated values to get equivalent EDR's for 1 month exposure. The same remark is appropriate here that was mentioned under deep effects; the time schedule indicated in the table will not hold for protracted radiation.

Shielding is of critical significance for protection from the surface hazard. The dose rate to clothed surfaces of the body will be appreciably reduced by the shielding afforded by the covering. Condit, Dyson and Lamb[21] have measured the absorber characteristics of several military uniform fabrics as shown in Table 5.

Table 5

ABSORBER CHARACTERISTICS OF FABRICS

Material	Wt/unit Area
Denim work pants	31 mg/cm^2
Cotton work shirt	17
Woolen pants	34
Knitted wool (sweater)	31
Close woven rayon	6.3

A normal two layer fatigue uniform would have absorption characteristics approaching one half-value layer for mixed fission products. Heavy clothing will be equivalent to roughly two half-value layers. Protection factors of 0.5 and 0.25 are then applicable to measured dose rate for areas covered with clothing.

Attenuation in air of beta radiation provides protection for upper portions of the body. However, direct measurement of the dose rate at the point of interest makes the necessary correction for this variable.

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The Determination of Internally Deposited Radioactive Isotopes in the Marshallese People by Excretion Analysis#

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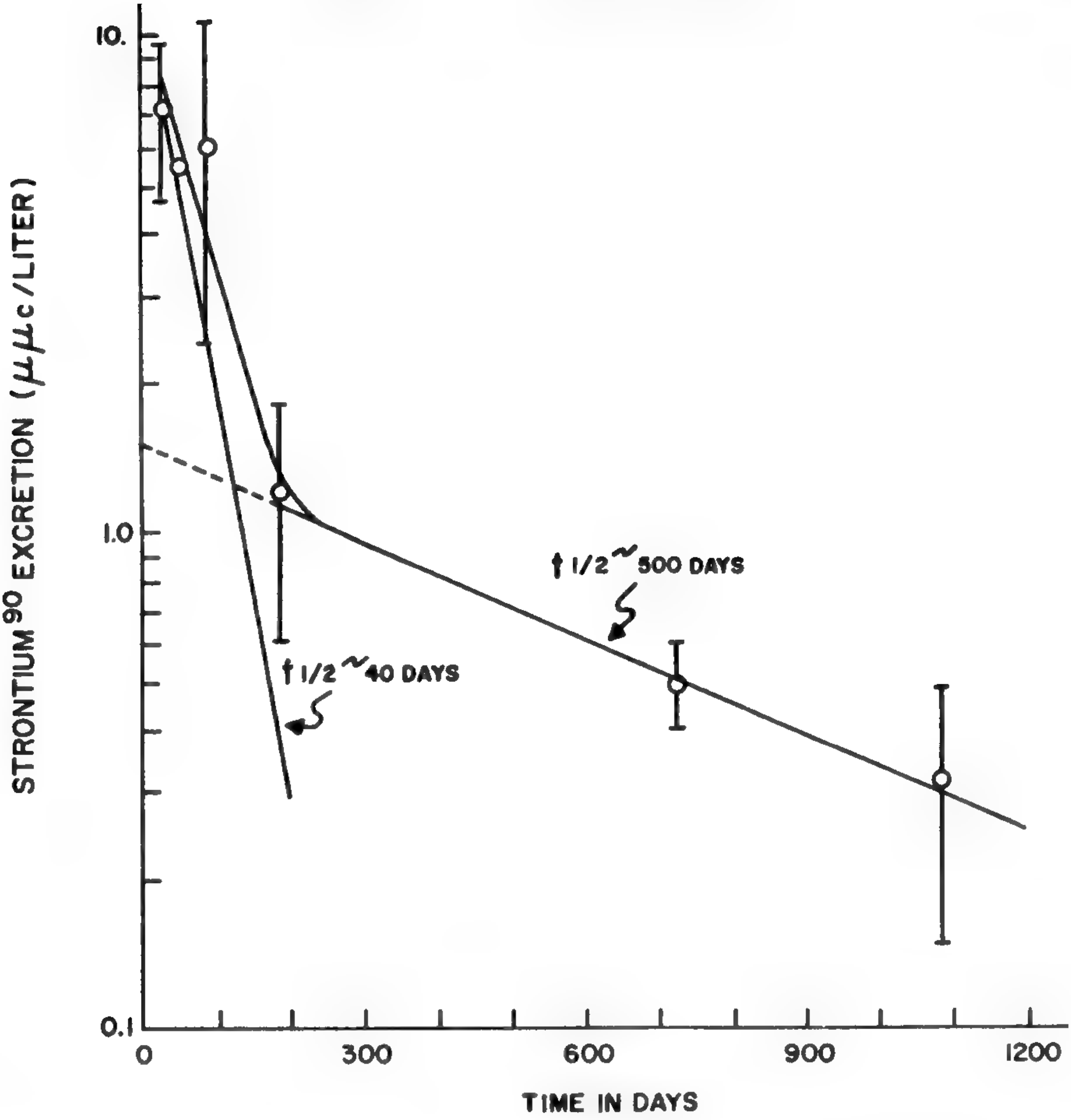
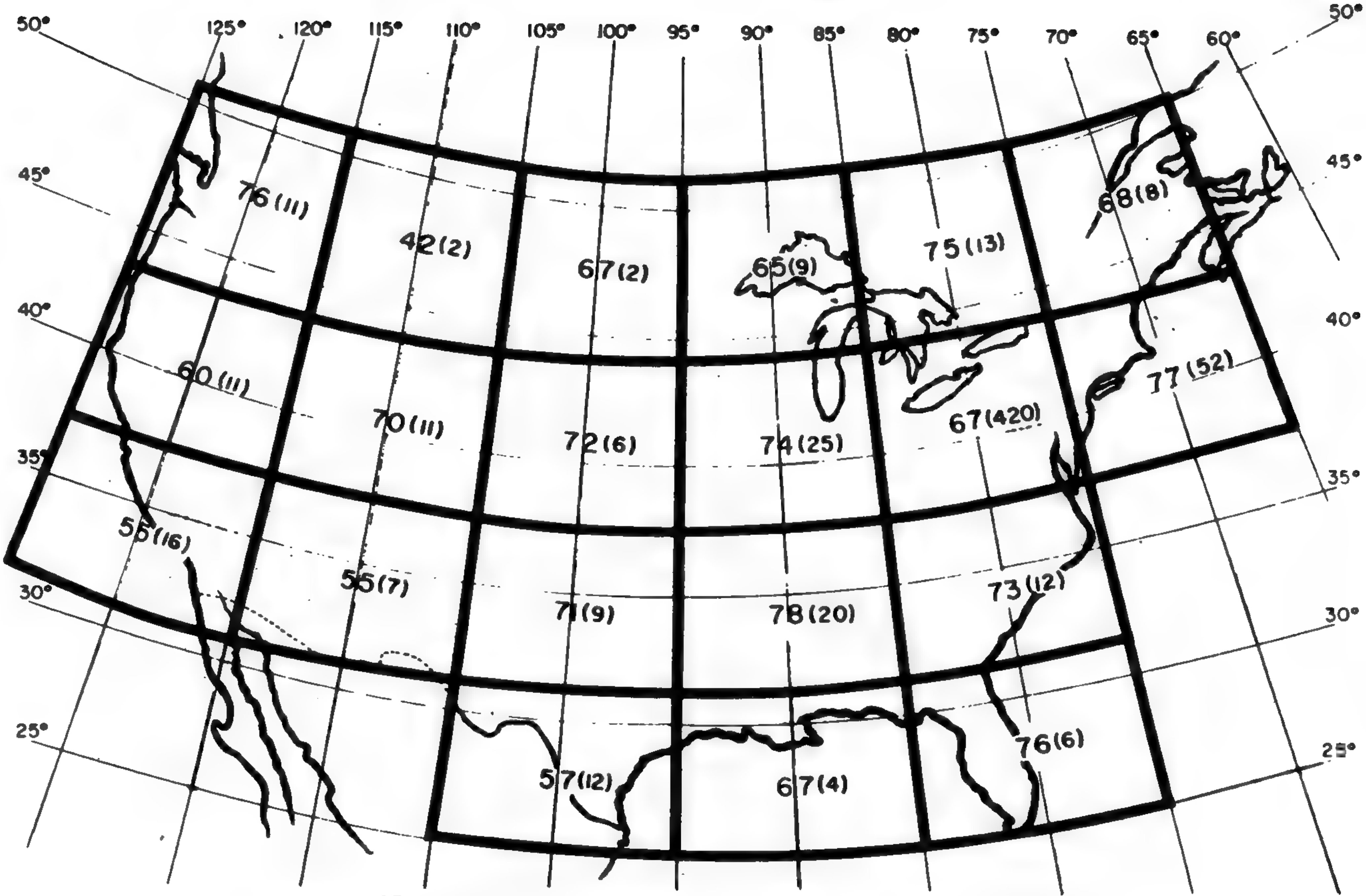


RONGELAP.

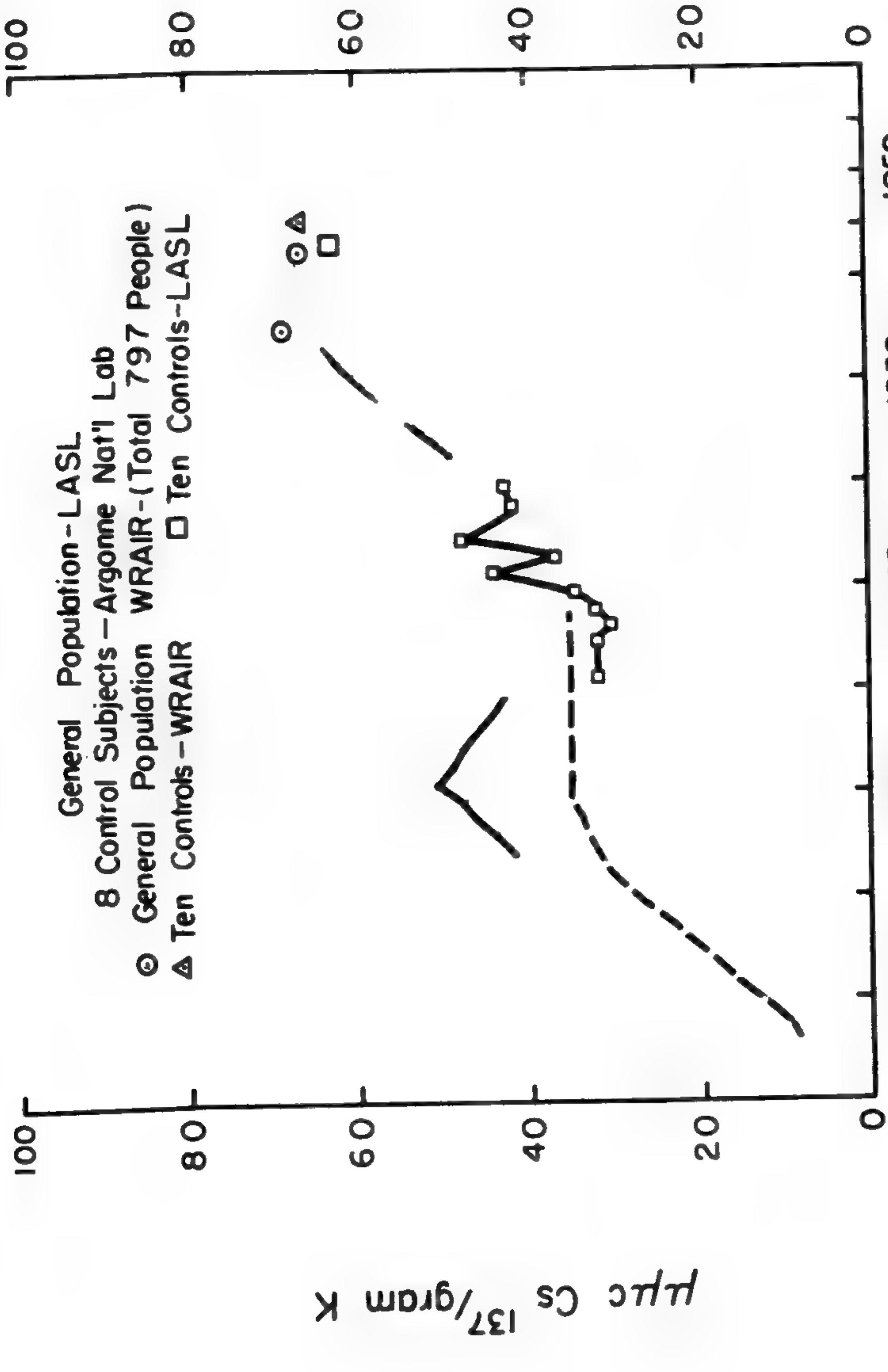
Figure 2. Excretion Levels of Urinary Strontium^{90} at Various Times After Exposure

The metabolic behavior of strontium as outlined in Supplement #6 of the British Journal of Radiology was used to estimate body burden, etc. from urinary excretion levels of strontium^{90} (Appendix). The fraction of strontium absorbed from the gastro-intestinal tract is 0.6 and the biological excretion rate from the total body is 190 days. Of the absorbed fraction, 0.25/0.60, about 42 percent is deposited in bone and the biological half-life is 4000 days.



CESIUM ^{137} LEVELS ($\mu\mu c/gmK$) IN NORMAL
U.S. SUBJECTS JULY 1958 – MARCH 1959
(TOTAL 797 INDIVIDUALS)

Figure 9



COMPOSITE DATA — CESIUM — 137 LEVELS IN UNITED STATES POPULATION

Figure 10

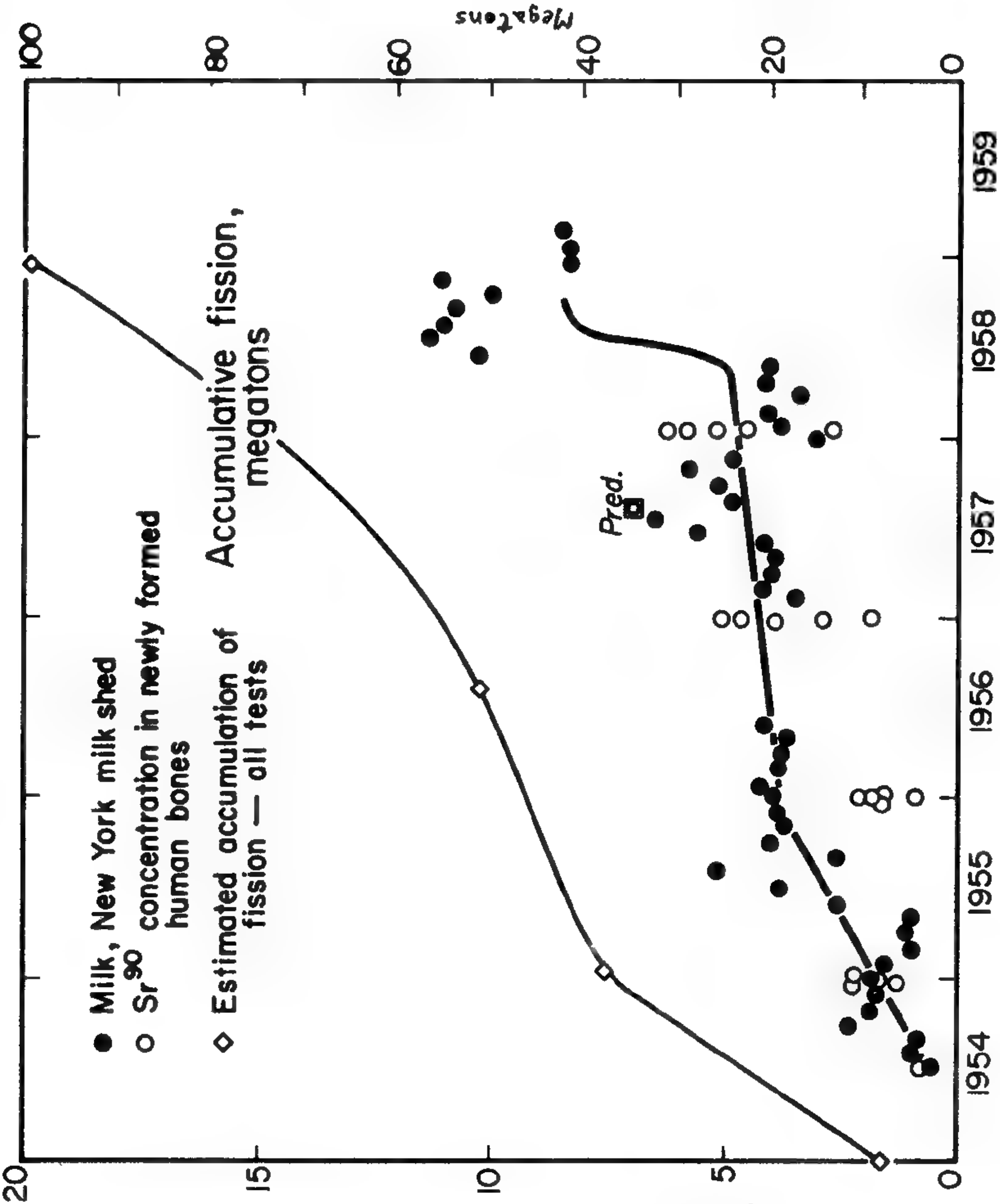
1 μμCi Sr^{90}/gram of Calcium in bone ≡ 2.8 mR/year

Calcium = 1/7th of bone mass.

Sunshine or Strontium Units (S.U.S)

(μμCi Sr^{90}/gram of bone calcium)

FIGURE II



92 fission megatons of tests to end 1958 give a mean of 10 μμCi Sr^{90}/gm Calcium ⟹ 28 mR/year to bone in the Northern Temperate Zone.

SURVIVAL ARITHMETIC

Heavy Fallout Area: 3000 r/hr at 1 hour

Dose during first year	12,000 Roentgens
Dose during first 2 weeks	10,000 "
Dose between 2 weeks and 1 year	2,000 "

EMERGENCY PHASE

10,000 Roentgens

OPERATIONAL RECOVERY PHASE

2,000 Roentgens

Shelter Shielding Factor	Emergency Dose	Reduction Factor	Operational Recovery Dose
10	1000 Roentgens	10	200 Roentgens
100	100 "	100	20 "
1000	10 "	1000	2 "
10,000	1 "		

Figure 1

Useful Radiological Defense Systems

Heavy Fallout Area: 3000 r/hr at 1 hr

System Number	Emergency Phase Countermeasures	Operational Recovery Phase Countermeasures	Dose during First Year (roentgens)
1.	6-month shelter with 0.01 residual number	None	320
2.	6-month shelter with 0.001 residual number	None	210
3.	2-week shelter with 0.01 residual number	0.1 reclamation	300
4.	2-week shelter with 0.001 residual number	0.1 reclamation	210
5.	2-week shelter with 0.01 residual number	0.01 reclamation	120
6.	2-week shelter with 0.001 residual number	0.01 reclamation	30

Figure 2

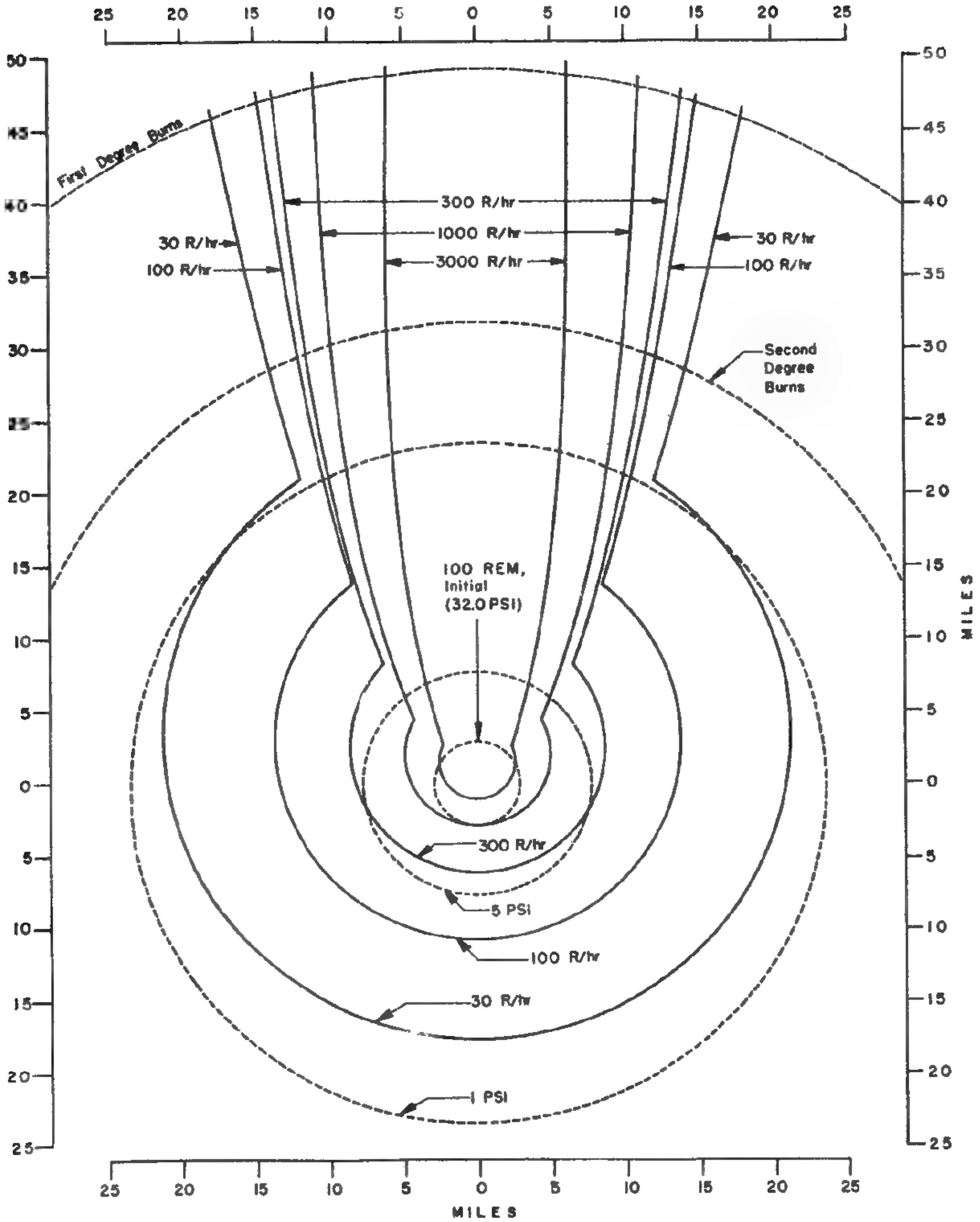


Figure 3

COMPARATIVE EFFECTS FOR A 20 MT SURFACE BURST

Residual radiation data — one hour reference dose rates — computed for a fission yield of 10 MT and an effective wind of 15 mph

BASED ON GLASSTONE ENW. 1957 WHICH SCALES UPWIND FALLOUT FROM 1952 "MIKE" TEST; OVERESTIMATING CLOSE-IN FALLOUT FROM LIGHTER CASED BOMBS WHICH PRODUCE LESS CRATER THROWOUT AND LARGE PARTICLES.

DR. TRUM:

TOTAL BODY IRRADIATION

In 1912, Regaud et al. wrote about the effect of ionizing radiation on the intestinal mucosa of the dog. Since that time many domestic animals have served the investigator in his quest for knowledge concerning the biologic effects of radiation. It is enigmatic that massive doses of radiation are required to produce observable chemical changes and yet relatively small amounts of radiation kill. If the total exposure is accomplished in less than 24 hours, between 300 to 600 r usually destroys about 50% of mammals. The midlethal dose for common species of livestock at 30 days (LD$_{50/30}$) may be found in Table I. Some species seem to be more radiosensitive than others. However, considerable variations in lethal response are found in families or even among individuals of the same species (Kohn and Kallman, 1956a). Vegetative forms such as bacteria are more radio-resistant than mammalian. Physical as well as biologic variations make comparisons of results from different laboratories difficult.

TABLE I
MIDLETHAL DOSES OF IONIZING RADIATION

Species	LD$_{50/30}$(r)*	Radiation≠	References
Dog	228-252	X-ray midline dose	Bond et al. (1956)
	265-312	X-ray air dose	Bond et al. (1956)
	335-530	X-ray, 21-500 r/hr	Casarett (1950)
	335	Co^{60} midline dose	Shively et al. (1956)
Rabbit	767	250 kvp	Grahn et al. (1956)
	1633	80 kvp	Grahn et al. (1956)
	1094	Co^{60}	Rust et al. (1955a)
Swine	618	Co^{60}, 50 r/hr.	Rust et al. (1954c)
Sheep	524	Zr-Nb^{95}	Trum (1955)
Burro	784	Co^{60}, 50 r/hr.	Rust et al. (1954a)
	651	Ta^{182}, 18-23 r/hr.	Rust et al. (1953)
	585	Zr-Nb^{95}, 20 r/hr.	Lane et al. (1956)
Bacteria	50,000-500,000	X or gamma	Schweigert (1954)
Parasites	25,000	X or gamma	Alicata (1951)

*LD 50/30 = The quantity of radiation in roentgens (r) that killed 50% of the test animals within 30 days after exposure.

LD50/30 has not been determined for bacteria or parasites and the near sterilization doses quoted for them above are given only to show the relative radio-resistance of these forms.

≠Mev = Million electron volts; kvp = kilovolt potential; r/m = roentgens per minute, a dose rate. Midline dose = dose measured at the approximate physical midcenter of an animal torso. Air dose = dose measured in air at point where the approximate physical midcenter of animal would have been during irradiation.

1. Dose

The expression of dose as used is itself variable since the roentgen, by definition, is an expression of quantity of energy absorbed by air. It is used to designate "free in air dose," "midline dose," and "absorbed tissue dose" as in Table I. Regardless of these variations, the biologic effects are in relation to the expressed dose. The dose is additive with various radiations (Vogel et al., 1955) and cumulative in a certain sense in so far as effects of previously received irradiations have a demonstrable effect upon the response to subsequent irradiations. The $LD_{50/30}$ for rats was reduced by 60% when reexposures were made at 60 days (Hursh et al., 1955).

2. Intensity

In man, it has been found that radiation of low intensity has little recognizable effect on the skin which has been explained as meaning that the lesions are being repaired as fast as they are produced. However, with radiations of moderate intensity at least, the effect is proportional to the dose.

TABLE II
LETHAL EFFECTS OF WHOLE BODY RADIATION OF DOGS

Rate (r/hr.)	$LD_{50/30}$ (r)
456.6	335
160.0	430
21 to 25	530

3. Dose Rate

Henshaw et al. (1947) reported a reduction of lethality by 70% of a given dose when the exposure time (dose rate) was increased tenfold. The amount of radiation to elicit a cutaneous reaction in man was doubled when doses were lengthened thirty times (McKee et al., 1943). Casarett (1950) found that the $LD_{50/30}$ for dogs at various roentgens per hour varied considerably (Table II). Mice exposed to similar doses in 90 minutes and in 24 hours from Co^{60} had an $LD_{50/30}$ of 930 r in one case and 1325 r in the latter (Vogel et al., 1956).

4. Fractionation of Dose

Fractionated doses or the continuous administration of radiation may differ in their effectiveness. However, if the fractionation is not great the difference may be insignificant. It may be possible to measure these differences but it is difficult to explain them.

Hursh et al. (1955) exposed rats to acute and fractionated exposures and found that a 600 r acute dose reduced the life span by 19%. When the dose was given in 10 daily doses of 60 r each, the life span was reduced 5.8% whereas there was no significant reduction in the life span of rats given 600 r in increments of 20 r a day. Kaplan and Brown (1952) reported that the fractionation and periodicity of exposure of black mice to radiation extended survival times and decreased the lethality of specific doses. Ellinger and Barnett (1950) demonstrated the effect of dose fractionation on mice. Brues and Rietz (1948) reported that chickens given 1000 r at a rate of 43 r/minute had 100% mortality in 14 days. However, if the dose was given in two equal exposures with a 40-minute interval, the mortality was reduced to 88%. Four exposures of 250 r with 20-minute intervals between them reduced the effect to 81% mortality. The burro has been given fractionated doses of whole body radiation until death (Table III) (Trum et al., 1953; Rust et al., 1954a, 1955b; Haley et al., 1955).

TABLE III
LETHAL DOSE FRACTIONATED TOTAL BODY IRRADIATION OF BURRO (CO^{60})

Dose/day	Survival time (days)	Mean lethal dose (r)
400	8.3 ± 1.4	3320
200	14.1 ± 3.3	2820
100	23.3 ± 1.0	2330
50	30.2 ± 3.3	1510
25	63.0 ± 13.2	1575

TABLE IV
MEAN SURVIVAL TIME FOR ANIMALS EXPOSED TO DAILY DOSES OF IONIZING RADIATIONS

		Mean Survival (days)	
Daily dose	Burro	Rat	Guinea pig
90-100 r	23.3	48.4	20.2
20-30 r	63.0	332.6	68.8

Swine have been given fractionated doses of 50 r/day until death (Trum, 1956) and accumulated a mean lethal dose several times greater than the burro. Thus we find that one domestic animal that seems to be more resistant (burro, $LD_{50/30}$, 784) than another (swine, $LD_{50/30}$, 200-400 r) and the burro, although quite different in their response to acute whole body irradiation, have a similar response to the fractionated doses (Table IV) while the rat is quite different than either.

When continuously irradiated a dose of 140,000 r caused death of mice within 20 minutes (Henshaw et al., 1946). However, after massive doses of 3500 and 14,000 r all mice lived 4 to 5 days. Burros, sheep, and cows lived in a constant flux of Co^{60} gamma radiation (40-50 r/hour) for 90 to 120 hours before total physical collapse (Trum and Rust, 1952; Wasserman and Trum, 1955).

5. Quality of Radiation

The quality of the radiation is a factor in biologic effects. By quality, we mean the type and energy of radiation or, in the case of X-rays, the characteristic spectral energy distribution. Arbitrarily, we will speak of low-energy X-rays as those under 140 Kev, relatively high-energy X-rays as those between 140-250 Kev, high-energy X-rays as those between 250 and 3000 Kev. All gamma

Table 1 Effect of Plowing.

Sr90 Levels by Fusion Analysis at Eleven Selected Areas in Nevada and Utah

Date of Collection, August, 1958

Area	Location	Sr90 Activity (0 - 1" Depth)	
		mc/sq mi	µµc/g Ca
Cultivated Agricultural Areas			
Alamo, Nevada	1 mi S	21.3	6.8
Moapa, Nevada	7.7 mi NW	16.3	2.5
Riverside, Nevada	0.4 mi S	22.7	9.6
St. George, Utah	1 mi SE	14.4	4.5
Hurricane, Utah	1 mi SW	12.4	3.5
Enterprise, Utah	0.7 mi N	7.46	8.6
Cedar City, Utah	2 mi SW of Enoch	16.7	4.6
Vernal, Utah	4 mi S	13.8	8.7
Virgin Undisturbed Area, Fallout Midline Locations			
Moapa, Nevada	8 mi N	142	38.3
Elgin, Nevada	3.8 mi SW	114	140
St. George, Utah	5 mi N	45.6	406
Enterprise, Utah	9 mi N	41.2	51.2
Panguitch, Utah	City limit, NW corner	31.9	14.9
Sunnyside, Utah	3.1 mi S of Columbia, Utah	67.2	202

SOIL DECONTAMINATION:

in the chemical composition of the soils as the organic matter decomposed.

The addition of lime ($CaCO_3$) and gypsum ($CaSO_4$) to acidic soils low in native Ca reduced Sr^{90} uptake by plants. Greatest inhibition occurred at treatment levels equivalent to from 2 to 5 tons per acre. At these levels $CaCO_3$ reduced Sr^{90} uptake about 60 per cent; $CaSO_4$ caused an 80 per cent reduction. These Ca amendments to the soil had little or no influence on the uptake of Sr^{90} from neutral and alkaline soils.

The uptake of Cs^{137} occurring as a contaminant increased as the K concentration in the soil was reduced by prolonged cropping. The addition of K to contaminated soils low in potassium content reduced the uptake of Cs^{137} by plants.

These radioecological studies have clearly revealed that (1) biological effect (or hazard) cannot be realistically assessed on the basis of measurement of only the gamma radiation field. Fission products from radioactive debris produced by man can be assimilated by animals with the maximum degree of accumulation not necessarily near the source of the nuclear reaction. Further, within a distance of 400 miles from the Nevada Test Site, the plant foliage is a selective particle collector. There has been no significant accumulation of activity through the root system. (2) Biological availability of fallout debris is strongly influenced by the conditions of contamination and by the physical and chemical nature of the contaminating material and its interaction with environmental factors. (3) Within 200 miles from the Nevada Test Site Sr^{89} and Sr^{90} are estimated to be less than 10 per cent of the total theoretical Sr^{89} and Sr^{90} generated by all detonations at the Nevada Test Site since the Ranger Test Series.

FRACTIONATION OF SR89/90 IN LOCAL FALLOUT.

Representative **Holifield**. Now, we are going to change our order of witnesses a little.

We have just received a phone call on Dr. Libby's airplane. It is en route between New York City and Washington Airport. So we are going to move up Mr. Herman Kahn, Center of International Studies, Princeton University, who presently is on leave from the Rand Corp. Mr. Kahn is a distinguished lecturer and educator and a student of this problem. He is one of the real experts of the Rand Corp., which has done many studies for the military departments.

If I could get Mr. Kahn not to talk as fast as he usually does, maybe we can follow him.

STATEMENT OF HERMAN KAHN,[1] CENTER OF INTERNATIONAL STUDIES, PRINCETON UNIVERSITY

Mr. **Kahn**. I will do my best.

Representative **Hosmer**. I think, Mr. Chairman, that Mr. Kahn and the people who have worked with him have given this subject the closest scrutiny that it has ever been given. I think we are fortunate indeed to have him before us.

Mr. **Kahn**. Thank you very much.

Representative **Holifield**. I notice that you have been here every day. You have seen a congressional committee in action over a long period of time now. I think you have a concept now of the laborious method by which we put things on record.

Mr. **Kahn**. I am impressed with how fast you do it. We spent a year and a half; and you have covered about the same ground in 4 days of testimony.

Representative **Holifield**. You see, you folks are not as expert as the committee.

Mr. **Kahn**. I would like to make it clear that I am appearing here as an individual. While many of the points I make will be based on work I and my colleagues have done at the Rand Corp. in 1957 and further work done at the university, the formulation, presentation, and opinions are my own. Because of the controversial nature of some of my remarks, it is very important to make this very clear.

I recently had occasion to give three lectures on thermonuclear war in New York City. One member of this committee and several members of the staff attended these lectures. I have been asked to summarize those aspects of the lectures which would be most appropriate to the function of this committee and in light of the testimony that has been heard.

The lectures were long. They took about 7 hours to give and there were about 4 hours of discussion available to amplify the remarks I made. And, on the whole, the audience was an expert audience. The reason for emphasizing these points is that I am going to have to be very light today; some of the things I will say need many qualifications, but for the sake of continuity of discussion and for the sake of just moving along, I will not be able to make all of these qualifica-

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tions. This inevitably leads to misunderstandings but given the constraints of time this cannot be helped.

Let me start by making some remarks about quantitative computations. The most important reason for being quantitative is because one may, in fact, be able to calculate what is happening. Many of the witnesses have emphasized the uncertainties of thermonuclear war but if we had raised Napoleon from the dead, and had him listen to these hearings he would have been impressed with the exact opposite notion; he would have been impressed with the relevance of quantitative calculations; impressed with the accuracy with which people predict what a nuclear war is like. One could not have applied the principles of physics, engineering and biology to an Indian war. In other words, when one drops a bomb with a certain yield and CEP one can then say: "These cities will be destroyed, these bases will be put out of commission, and so on with at least moderate reliability. In particular, one can have reasonably good lower estimates of the damage.

This is of some real interest; before World War II, for example, many of the staffs engaged in estimating the effects of bombing overestimated by large amounts. This was one of the main reasons that at the Munich Conference and earlier occasions the British and the French chose appeasement to standing firm or fighting. Incidentally, these staff calculations were more lurid than the worst imaginations of fiction.

In our case, when we say a building falls down, it very likely does. When we say a person is killed with a thousand roentgens, he very likely does die. Our calculations are more likely to be underestimates than overestimates since the effects we have overlooked are obviously not in the calculations. This means that the picture of horror that is painted of a war today is in some sense reliable. It really may happen as described.

On the other hand, one can still overestimate the horror. I would like to associate myself with the spirit of the last witness' testimony in emphasizing the importance of a nation surviving, and of looking at what survives in addition to what is destroyed. I do not like his analogy of the handicapped individual, because that gives the feeling of being crippled for the rest of one's life. One never really recovers from a handicap such as the loss of an arm. One can only adapt to the loss and live with it. This is, in fact, the picture most people have of a thermonuclear war—of a sort of permanent setback, if not a form of annihilation. I also would like to point out this is an expert picture, just as in World War II, but more so. Most of the experts, whose duty it is to plan for wars or who write about the subject, do have a picture of a war which is even more lurid, than that which has been painted in the last 4 or 5 days.

It is because of the enormous impact that the introduction of thermonuclear weapons has had on people's notions of what a war is like, that one has had the extreme, I might say almost 100 percent, dependence on the theory of deterrence. This has been coupled with an unwillingness and an inability, a psychological inability, to analyze what deterrence means. In other words, when one has to depend on something working, one cannot afford to question the underlying assumptions; it would be too disturbing, if one did, too disturbing for ourselves and for our allies, if we raised questions that shook our faith in the notions.

American tenacity, American purpose. Their estimates lie between 2 and 20 million. And it is important, you understand, that they have a proper opinion, too. I have no feeling at all what a Russian estimate would run. Absolutely none. I do know it might run very high. The Russians lost something like 10 percent of their population, and, they claim, about one-third of their wealth, in World War II. And they know they recovered from that. While they are still appalled at the damage they suffered, they can think in these large terms. So the Russians might be very impressed with the U.S. capability, and the United States might in fact have both the will and the capability, at a time when the Europeans did not believe it. This is a very possible situation, and in some circumstances, a disastrous situation.

It is important, in other words, to differentiate very sharply between what I have called Type One Deterrence, which is trying to deter a direct attack on the United States, and what I have called Type Two Deterrence, which is trying to deter an extremely provocative action. In the first case, many things enter Russian calculations as to whether they should attack the United States or not. But one of the most important things which will enter their calculations is their estimate of what would happen to Russia if they struck the United States at a time of their choosing and we strike back, with a damaged force, in the teeth of an alerted air defense, and in some instances after the Russians have evacuated their cities.

Type Two Deterrence, deterring extremely provocative actions, involves a quite different calculation. It is again a Russian calculation. Only now the Russian asks himself: If I do this very provocative thing, which is less than a direct attack on the United States, but which is still very provocative, will the Americans start the all-out war? That must be influenced by whether or not the Americans think they can survive our counterattack. And that means the Americans must calculate that they strike first and we Russians strike back with a damage force. Things will be completely reversed from the Type One Deterrence calculations.

I might point out that in both World War I and World War II it was Type Two Deterrence we were talking about. That is, the British declared war on the Germans, and not vice versa.

Representative DURHAM. In those conditions you would not think we would strike back? Is that true, Mr. Kahn?

Mr. KAHN. No, I believe, and I should make this very clear, that if the Russians did something very provocative in Europe today, we would live up to our alliance obligations and strike.

Representative DURHAM. I was thinking about the 6, 8, or 10 years you were talking about.

Mr. KAHN. I believe that under current programs we will not.

Representative HOLIFIELD. Now please define the current programs.

Mr. KAHN. We have certain programs in the field of air and missile offense and air and missile defense, and civil defense. Add them all up, and it is hard to believe that we would be willing, and I do not wish to be specific in years, because this would get us into the classified field, but at some time in the future we will in fact be outbid, under current programs.

I hope later to get into the philosophy of the deterrent forces, and this is very much connected with this notion.

I should make one other small point before I go into the systematic discussion, even though we are running out of time. And this is the question of the symmetrical character of what I call Type 1 Deterrence. In order to make it easier to remember, let me use the same terminology the British used. The British refer to the type 1 deterrent as a Passive Deterrent, because they argue it takes no act of will. In other words, if he strikes you, you will strike back. It does not take any courage or any will. They refer to Type 2 Deterrence as an active deterrence, because it takes an act of will. You have got to be willing to strike the enemy when he provokes you by striking a third party. It is not automatic.

Let us now consider Russian Active Deterrence for a moment, and ask ourselves: Is it easy to deter the Russians? Can we afford to provoke them as far as we wish to go?

Let me give an example. In 1956, there was a revolution in Hungary which the Russians suppressed. There was at that time much pressure on the United States to intervene in that revolution to support the Hungarians. I myself felt rather strongly we should do something. However, I wish to ask the following question: If we had intervened, would the Russians have accepted that intervention, say in 1956? Would they accept it in 1960? These are different situations. It is possible that we did more than not intervene. There are rumors—I do not know if they are true or not—that we broadcast to the East Germans and the Poles not to rock the boat, that American aid was not on the way if they did. There are reasons for worrying about a satellite revolt spreading and, if we had intervened, it is quite clear that there would very likely have been a widespread satellite revolt. Particularly if the Russians did nothing, if they just let us get away with it. After all, some of the satellites revolted without any American intervention.

A satellite revolt is a very big thing to the Russians, and they might not be willing to stand for it. Much more important, the Russians are greatly concerned with internal stability. Most Russian experts that I know of think of the Russians as having a very stable government, unlikely to be upset even by really quite catastrophic events. But it also seems to be true that the Russians do not think of themselves as quite that stable. They worry about internal revolution in Russia more than we do. And they might think of a successful satellite revolt as an intolerable event that might lead to the end of the regime.

They would, I think, be under pressure to fight if we intervened in Hungary. If the fight was on a high explosive basis, I think we would lose. If the fight was on an atomic basis, I think we would probably still lose, but now there would also be side effects. If the fighting were limited to Hungary, there would probably be widespread destruction within Hungary because neither of us would wish to lose without making a major effort. If we tried to limit the damage by attacking supply lines in rear areas we would be getting into Russian territory. Now, the Russians might think at this point that at any moment the war could erupt either into a satellite revolt or into a large scale attack on Russia. They might be particularly willing to worry about the latter because they would find it very hard to believe that we intervened with the expectation of losing. In any case, it is a very large war being fought near Russia. They might then ask themselves the following question: Rather than wait for this war to erupt into a satellite revolt or into an American surprise attack on our strategic force, maybe it is safer for us to hit the United States and thus at least assure our getting that all important first strike—at least if we hurry.

In other words, they might argue that going to war is very risky, but possible less risky than not going to war. At this point we must ask the question: How risky is it for the Russians to go to war?

Well, in late 1956, it was very risky for them. We had a very large strategic force and one which was very alert. Even if they attacked the United States and caused much larger levels of damage than that discussed here, our strategic force would have flown away before they could have damaged it. ASSUMING BOMBERS, NOT FAST MISSILES!!

This situation may not, however, be as true in the future, for a number of reasons.

I would like to make this one observation at this point. If the Russians can limit our attack on them to about the size of this attack on the United States, then if they have made very modest preparations, they do not suffer a great deal of damage.

What do I mean by this? I mean that if they can evacuate their civilians to places of safety, radiological safety; then we can't kill very many Russians. There are lots of places to evacuate to in the Soviet Union. Let me give some orienting numbers. There are less than 50 million people in the largest 135 Russian cities. As far as we can tell it is perfectly possible to evacute 80 percent of this urban population and have all vital functions in the cities performed. This would leave only 10 million people at risk in 135 cities. Having been alerted, these could evacuate on very short notice. In addition it is very difficult to destroy 135 Soviet cities in a retaliatory blow. I am not saying we could not have done it. I think we could have, in 1956. But it is a difficult thing to do. You can see it is difficult. In any case it is a larger attack than this one.

Even if it did not kill many people such an attack would cause a lot of economic damage in Russia. But the Russians claim to have lost one-third of their wealth in World War II, and they recovered from it. In fact they recovered by 1951. And they know they recovered from such levels of damage, because they mention it. In other words, the Russians know that it can pay to accept very large amounts of damage, rather than to surrender, because they have actually gone through the experience. And while that is a very hard way to learn, it is also a very convincing way to learn by having actual experience. This doesn't mean they would be glad to repeat the experience—only that they may be willing to under less pressure than we would be willing to.

I mention both of these cases, because I want to put the rest of my discussion in context.

One not only has to ask himself what it costs us to go to war under certain circumstances, how do we feel about it, how do the Russians feel about it, how do the Europeans feel about it, but also the same set of questions about the other possibility—about Soviet willingness

Mr. Kahn. No. But I am saying that it is 10 megatons if uniformly spread. Multiply by 10 to take account of decay and weathering. Multiply by another 10 to take care of nonuniformities.

Now, the calculation is misleading. But it is persuasive. And you have to know why it is misleading. Otherwise, you will be persuaded.

It is wrong for many reasons, one of the most important being that the peacetime standards are probably not legitimate for the postwar world. It is also wrong because it does not take account of the fact that we will do many things to alleviate the problem.

I am not a medical doctor, and it would not be appropriate for me to suggest possible postwar standards. But just for the purpose of discussion, let me do exactly that, to give a feeling for some of the considerations which might come up.

I suggest that we would be willing to accept something like 50 to 100 sunshine units in our children, in the postwar world, not because we are happy about the idea but because it is a little difficult to achieve much less than that unless we make some preparations.

Representative Holifield. We have been using the term "strontium unit" rather than "sunshine." Some of us are allergic to this term "sunshine." We prefer the term "strontium."

Mr. Kahn. I could not agree with you more. Strontium 90 is manufactured by men. Sunshine is not. Let us keep it to a manmade object.

Senator Anderson. I think that term sunshine came because the first time they said if the fallout came down very, very slowly, that was good for you. And then later they said if it came down very fast, that was good for you. We decided to take the sunshine, in view of everything.

Mr. Kahn. I prefer not getting into that debate. I deal in a number of controversial subjects, but I try to keep the number down.

To continue, one might be willing to accept 50 or maybe a hundred, even, strontium units in our children, if we had to. Let us call food that would result in this or lower levels an A food. The A food would be restricted to children and pregnant mothers. One might then also have a B food which might be about 10 times as contaminated as the A food. This would be a high-priced food, available to everybody. There might then be another grade of food, a C food, which would have another factor of 10 more contamination. This would be a cheap food available to all. We are now talking about having up to 10 microcuries in new bone, which is quite a bit.

But I might point out, no one has ever seeen a bone cancer directly attributable to radioactive material in the bone at less than the equivalent of 20 to 30 microcuries. Now, we are reasonably sure that smaller amounts will cause bone cancers in a statistical sense; but I would guess that at least an adult insurance company would not raise its premium very much if one lived on food with that amount of strontium 90 in it. Ten microcuries of Sr^{90} per kg. of calcium would mean a dose of about 20 roentgens a year in the bones. This would probably cause less than a year's loss of life expectancy. The C food is especially acceptable if it is mainly restricted to adults who would pick up much less Sr^{90} than children would.

Then I would suggest another factor of 10 for a D-food, which is not available to the general public but is restricted to people over 40, or maybe over 50. It is difficult to kill a man over 40 or 50 with Sr^{90}. People of this age group do not absorb very much, and it takes 20 or 30 years to get bone cancer. One dies of something else before he does of bone cancer.

One reason why I am suggesting setting up tentative standards now is that we really have to have, before the war, some notion of what we are willing to live with, to guide research, to guide planning, and to eliminate hysteria in a crisis.

There is another reason why it is important to set up in peace the war and postwar standards we think we may have to adopt. In addition to determining these standards, the Government should formally publish them in a permanent looking form that will be available for at least postattack or postcrisis distribution. It is not really necessary to distribute all of the handbooks prewar as people can usually read them either during or after the crisis or attack, though they should be made available to all who are interested. It is, however, important to print them ahead of time, not only so that they will be immediately available, but also so that people will trust the information in them. In any such crisis many will be cynical of the integrity of the Government and will argue that the Government says these standards are acceptable because it must say so, that conditions are such that it has no choice, but that in fact the standards will result in a drastic level of casualties. The knowledge that the standards were set up in peacetime after due care and debate should be reassuring.

I am not suggesting we should publicize the existence and character of the postwar standards. I am not suggesting we should tell everybody they will get bone cancer. I am merely suggesting that the manuals be printed, stockpiled, and a small circulation made to those who are interested.

I had a discussion with a rather senior official in the AEC suggesting this. He looked at me rather amazed. They aren't very happy at the thought of putting out anything that could be construed as suggesting they are underestimating the Sr^{90} problem.

Incidentally, this official asked me, "What do you think the difference in price would be between the B and C foods?"

I said, "About 5 or 10 cents a quart."

He said, "You could not sell one for less than $50 a quart difference."

If it is in fact true that people would not be willing to eat foods contaminated with a microcurie or so of strontium 90 per kilogram of calcium, then I think we are not going to recover very expeditiously from this war.

It is only because, for a short time, we are willing to eat such food, that I believe our recovery would be rapid. If this is not true, then we are either not going to have food, or we will put much energy into obtaining food that should go into other reconstruction projects.

It is important to realize that world agriculture would soon adjust to this problem. We would find the United States growing nonfood crops and meat and Argentina growing dairy products, and so on. In a relatively short period of time, if there is recovery, the patterns of agriculture will adjust to the contamination, and while food may cost a little bit more, it will not be excessive in either price or contamination.

Therefore, in all likelihood, the Sr^{90} problem is a short-term problem, but it still must be treated objectively and soberly, without any unnecessary panic or hysteria for that first 3, 4, or 5 years. I should also mention that there are other alleviating measures that will help.

I would like to repeat, it is really important that we treat this and other problems ahead of time, because if we do not, and wait until the crisis, we are going to find somebody raising this question, and we will not be able to answer it convincingly on that day. We must have thought this thing through long before the Russians ask us to think it through. Among other reasons, because it has to be debated.

Representative HOLIFIELD. What you are advocating is to take these problems that are imminent and put them on the table, talk them through, and get the most authoritative information on each one now, so people will know what they face?

Mr. KAHN. For this purpose I am not really so much interested in the people, though I have the same interest in them that you have. I am talking about the experts knowing what they face, the men who advise the Government during the crisis. You do not want them panicking. In fact, to be really frank, if there was any way of getting the initial discussion restricted to just 10,000 people, I would like to do it that way.

Representative HOLIFIELD. Why?

Mr. KAHN. I want to get as many technical arguments as possible out of the way before we fill the headlines with them. I prefer these technical arguments occurring not behind closed doors but in the technical arena. Unfortunately we cannot do it that way.

Representative HOLIFIELD. In other words, you believe the scientists should come forward with the scientific information and settle the fights among themselves before submittnig the conclusions to lay people, who are not technically qualified to form judgments. Is that your position?

Mr. KAHN. I don't think that is completely possible in our form of society or even desirable, so I am not recommending it. But if it could be done a little bit like that, I would prefer it.

You do get a lot of misinformation in the headlines, and people do get overly scared, or underly scared. They are entitled to this information, they should have it, but they are not entitled to misinformation or even unsophisticated notions.

Representative HOLIFIED. You are not denying the right of any individual to make any conclusion on the basis of a moral or a philosophical or a spiritual conviction?

Mr. KAHN. Absolutely not.

Representative HOLIFIELD. But what you are saying is that the information should be available for those people who wish to make the basic conclusion on the facts. Then let them apply them in any way they want to, morally, philosophically, or spiritually?

Mr. KAHN. Right. To give you an example of the difference, in the 1957 hearings on fallout, people were talking about things like a fraction of a roentgen. And yet they were using very cataclysmic language. In the current hearings, in reference to much higher amounts, witnesses are always adding words, to the effect, incredible as this is, the country can survive it.

Senator **Anderson**. Has the National Academy of Sciences done anything along this line?

Mr. **Kahn**. Yes, there is a great deal of information available today. And it is not the technical information that is in dispute, really. It is how you feel about it. What is your attitude toward it? People have not really evaluated this technical information in terms of reasonable postwar standards. This is not a technical decision in the sense of something one learns in school or even in a laboratory. These are things which Congressmen and the public must be involved in. But it is well to get the debate some distance among the experts before it is opened up. That is all I am saying.

Senator **Anderson**. But when the Federation of American Scientists want to talk about this, people say, "Oh, maybe some of them are left-wingers." That is the major difficulty, is it not?

Mr. **Kahn**. It is one of the major difficulties. I have a paper listing 52 Nobel laureates who signed a statement to the effect: "All nations must come to the decision to renounce force as a final result of policy. If they are not prepared to do this, they will cease to exist." If you look at that list of 52 of our most distinguished scientists, you cannot dismiss them as just a bunch of left-wing radicals making this extreme statement. Most of them are just scientists who have either made or think they have made, seen or think they have seen, calculations which imply just what they said. But the statement is extreme. It says, "All nations," and says, "cease to exist." It does not say "damage." Well, this is the kind of remark you get early in the discussion. It would be better if the statement could have been debated some before it was released.

Now, there is an important point here. I am not saying that a war that occurred in the year 2000, or even in 1975, might not be almost as cataclysmic as this. It is getting worse on a year-by-year basis, and many of my friends tell me, "Herman, you really shouldn't go around saying that people can fight and survive wars, because, after all, 10 or 20 years from now you may be obsolete, and it takes 10 or 20 years to explain things to people, so let's start now."

That is a judgment which I think (a) they have no right to make, and (b) is wrong. These problems of ours must be met on a year-to-year basis. We cannot get to 1975 if we do not get to 1960 and 1965.

Furthermore, no matter what your picture of a future utopia is, and we all have one, or you cannot live in this world, you have to get there, and getting there may be harder than drawing one up.

In other words, we have to be able to meet the challenge as they come on a year-by-year basis. This means we have to understand what the problem is on a year-by-year basis. Transition arrangements are just as important as final states.

Representative **Hosmer**. Are you not to some extent making an evaluation of what you would have in 1965, or be willing to accept in the way of a world in which to live; in one case if there was a nuclear war, and in the other case if you avoided it by accepting some other alternative, which might produce some comparable situations that were less acceptable than those created by the war?

Mr. **Kahn**. That is part of what I have been saying. But it is difficult to limit technological progress. Let me give you a feeling of what the future may hold. The public press has referred to begaton bombs, for example. I am not saying such bombs are possible or not possible, but there is no law of physics which says they are not possible. You just cannot limit man's technology, and therefore it might literally be possible for human beings to blow the world into little pieces at some date within our expected lifetime, well within it, maybe. And it is clear that when that instant arrives, if you are going to fight a war at all, you have to fight it carefully, or maybe you cannot fight at all.

Unfortunately, war has had an important role in human institutions for many years now. The regulatory effect of the threat of force has also been important. It is a little hard to believe that all of our problems are going to be solved. It is hard to believe that just because you cannot strike the other person any more, that he will then behave very well.

I would like to emphasize: Britain declared war on Germany in 1914. Britain declared war on Germany in 1939. If they had not been able to declare war in either of those 2 years, they would have had to let the Germans do whatever they wanted to do.

However, it may well be, though, that we will face problems in the near future which are just not solvable by the techniques we have used in the past. In fact, that is true today to some extent. And it may well be that we should start on this new world right now. But it is a mistake to say that the new world has arrived today. It does not seem to be true.

I have a book with me today which I recommend to those who want to exaggerate the impact of thermonuclear war. It is called "Munich: Prologue to Tragedy," by Wheeler Bennet. Among other things Wheeler Bennet discusses why Chamberlain and Daladier folded. When they returned from Munich they were cheered by their people in Paris and London, because war had been averted. Over that weekend some people began to understand that war had been averted by a sellout of the worst sort. And on Monday some few were prepared to criticize. But if you read the debate, you noticed something very significant. The people who criticized Chamberlain and Daladier, with a couple of exceptions, did not criticize them for not going to war; they said, "Hitler was bluffing, and you should have stood your ground."

As far as we can tell, Hitler was not bluffing. The men who were in the room with him could see he was not bluffing. It was easy for the people back home to say he was bluffing, but not for the men who had the decision to make. The German people did not want war. The German Army did not want war. They literally threatened to have a military revolution. But Hitler seems to have been willing to have a war if he couldn't have his way.

We may be asked that same question. If the other man is not bluffing, and he may not be, then we have to ask ourselves, "Are we willing to fight or are we not? Do we have an alternative to peace?" It is just that simple.

Let me mention one more thing about the strontium 90 problem which gives one more reason why people are so concerned.

If you had tried to predict the effects of this kind of contamination before we had carried out these worldwide experiments, the testing in the Pacific and the Soviet Arctic, you would have probably estimated the concentration in new bone as about 10 times larger than it is.

It turns out that the chain which brings Sr^{90} into the human body from the fallout to the grass, to the cow, to the milk, to the intestines, to the bone, discriminates against strontium 90 versus calcium. This is purely fortuitous. Nobody would have predicted it ahead of time. If you had been rather subtle in your calculations, you might have realized this uncertainty existed and taken a factor of 10 against you. That would have made the predicted problem a hundred times worse than it is.

Now, certainly if the problem came up very suddenly in a crisis, and you wanted to make a conservative calculation, you would have taken the 10 against you, and would have predicted a problem 100 times worse than it is, and you would not be talking about A, B, and C foods, but about the abandonment of the country or at least of agriculture. We were just lucky, so to speak.

If you look at the other problems which bother people, the carbon 14 problem, for example, it is not so bad, but it has a similar characteristic. One of the problems that bothers people most about it is that 10,000 years after the war is over carbon 14 will still be causing genetic damage. That is a horrible thing to think of—you have a war today, and 10,000 years from now people are still suffering from the consequences of that war.

But from our point of view that damage, though acceptable over 10,000 years, is much less acceptable if it is taken in, say, 20 years. If carbon 14 had a lifetime of only 20 years, you would be much less willing to face the possibility of a war and more willing to appease. And if it was a really big war you could not face it, because you would be getting thousands of roentgens in one generation rather than 50. SPECIFIC ACTIVITY $\propto$ 1/(HALF LIFE)

The point I am trying to make is that you cannot say, as people are sometimes tempted to say, that man has faced plenty of things in the past and therefore can face this also, that man always has and therefore always will rise to the occasion. No man can rise to the occasion with a thousand millicuries of strontium 90 in his body or a dose of 3,000 roentgens.

The reason why I and my colleagues feel that the United States or Russia can survive this war is because we have experimental and theoretical data and have made calculations.

To put it in the words of the physicists, there is no conservation theorem which states one can get through this war. It takes data and calculations to show it.

That is a very frightening thing, because that means you are depending on theory. And, as you know, theories have gone astray. Even bridges occasionally fall down.

Now, if you look at the kinds of wars discussed in the last 4 days, there is such a large factor of safety present—and I think some of the testimony was pretty extreme, but most of it was very responsible—you can really feel that you can get through a war in the near future. Nobody today knows whether you could get through a war 30 years from now, even if you spent tens and hundreds of billions of dollars, because the problem may get much worse. We estimate that just to answer some of the relevant questions would cost $200 million. These are complicated questions.

Representative HOSMER. You did make some calculations, I believe; what it would take in time and resources to achieve a return to prewar standards.

Mr. KAHN. Let me do that in just one moment.

I am not trying to say one cannot face wars in the more distant future. I am just saying we do not know. We should find out.

If you look at an attack such as the one this committee looked at, you will find that more than half of the wealth of the country survives the attack. You find that much more than half of the population survives. You find you have a great many resources left over. Many people think of this as a very misleading observation. That is, they think of a human society as being similar to human bodies. If you destroy one vital organ, the body dies. The hair cells might linger on for a while, but eventually everything dies.

Now, that is not our view of society. It is rather interesting that before World War I, many experts had the same view of international trade. They argued that wars had to be short, because nations were so dependent on international trade that if it was cut off they would die. Today we know that this is not true and we use the same international analogy in our study.

We divide the country into two separate countries, an A country composed of, say, the largest 50 to 100 metropolitan areas. (A metropolitan area includes neighboring suburbs.) Then we say there is a B country, the rest of the country, the medium cities, small cities, towns, rural areas.

We notice that the B country has a large population, well over 100 million people, that it has a lot of wealth, that even if the A country was completely destroyed, the B country could probably not only survive that destruction but rebuild the A country in something like 10 years.

Now, we have no faith in that calculation. It is a calculation which nobody knows how to make. But we do not know whether the calculation is optimistic or pessimistic. It is just the best we can do.

My time seems to be running out, so let me finish by making some caveats. For this size of attack I do not know if these caveats are very important, though it would be important for a much larger attack.

We believe that if one dusted the United States with the fallout from this kind of attack and did no other damage than if we had made cheap preparations for attacks of the size studied by the committee and expensive preparations for much larger attacks, we could handle all the radioactivity problems. We believe that if you evacuated the A country and destroyed it totally, these 50 or 100 largest cities, and did nothing else, that we could rebuild these cities in 10 years or so.

We also believe that if you did nothing else but just kill one-third of the population of the United States, the other two-thirds would not commit suicide. They would bury their dead, go into a period of mourning, and then life would go on. It is just that simple.

But there is a very important question which we never even looked at. What if you do all of these things together and do many other things?

Certain data were presented yesterday on ecological effects, these large fires and things like that. I think that data is a little premature.

It probably does not correspond to a war of this sort, but a war maybe 5 or 10 years from now. But still you are doing things like that. You are burning large areas of the country. You are killing more insects than birds, and other things of that nature.

Now, it is our belief, not strongly held, but moderately strongly held, that for an attack this size, these interacting and unlooked at effects will probably not be crucial. For a larger attack, we are certain they are very important and have to be looked at insofar as they can be looked at.

Senator ANDERSON. I asked a very able scientist one time what he thought the outcome of a nuclear war would be. He said, "Well, if you would give me one of the caverns in your State where I can hide one plane and put one bomb in it, I would wait 3 days after the war started, and then I would try to find the one remaining person in the world and kill him with that bomb." He felt it would be total destruction.

You do not think it will be that way?

Mr. KAHN. It is not like that at all, so far as we can tell.

Senator ANDERSON. At Sarajevo there was one little rifle shot, but before we got through there was quite a little shooting.

Mr. KAHN. In the three lectures I try to discuss how wars terminate. This is a very complicated and uncertain subject. But, like anything else, one can conjecture and speculate. As near as I can tell, in most wars one side or the other gets a commanding lead very fast. In other words, you do not go down together. One side gets very much ahead. And then the only question that arises is a variation of the following. The side which is ahead can tell the side which is behind, "Unless you surrender or negotiate, I will physically destroy you. I will literally kill every point of resistance. I prefer you surrendering (a) because I am a humanitarian, (b) because you can hurt me while you are going down and I prefer that you don't hurt me any more than you have." The side which is behind has the choice of trying to use its remaining power of destruction to get a good bargain, but its bargaining position is weak.

Now, if you look at this bargaining in detail, you notice that there is a great pressure of time, communications, control problems. It is a very bizarre world; it is not like an international conference at Geneva. One cannot propose complicated diplomatic formulae. The demands must be very simple. Whether they will be accepted or whether the war will be fought to the bitter end is unpredictable. Once you get into this kind of thing, you can only conjecture what will happen. But one thing seems relatively likely, a war in which both sides go down together and fight it out to the last plane and so on is a very hard war to envisage, if you look at exercises, maps, and the effects of modern weapons. It just does not seem to be like that, for most wars. The only one in which it seems to be possible is one where the war starts accidentally, where no side made any real preparations.

But if one side gets in a very good first strike, it will in all probability, in a very real sense, win the war.

Senator ANDERSON. I am afraid that we are going to have to terminate here.

Representative HOSMER. Before we do go, I would like to call attention that on page 8 ways and means are spoken of to ameliorate a thermonuclear war. They will be in the printed hearings.

(The prepared statement of Herman Kahn follows:)

MAJOR IMPLICATIONS OF A STUDY OF NUCLEAR WAR[1]

Herman Kahn, Rand Corp.

The general belief persists today that an all-out thermonuclear war would inevitably result in mutual annihilation, and that nothing can be done to make it otherwise. Even those who do not believe in total annihilation often do believe that the shock effect of the casualties, the immediate destruction of wealth, and the long-term deleterious effects of fallout would inevitably jeopardize the survival of civilization.

A study recently carried out by the author and a number of his colleagues at Rand, and privately financed by the Rand Corp., has reached conclusions that seriously question these beliefs.[2] While a thermonuclear war would be a catastrophe—in some ways an unprecedented catastrophe—it would still be limited catastrophe. Even more important, the limits on the magnitude of the catastrophe might be sharply dependent on what prewar measures had been taken. The study suggests that for the next 10 or 15 years, and perhaps for much longer, feasible combinations of military and nonmilitary defense measures can come pretty close to preserving a reasonable semblance of our prewar society.

As long as we think of a thermonuclear war as a sort of end of history, we may not feel acutely uncomfortable about placing all of our reliance either on deterrence or on measures to alleviate tension, as this seems to be all we can do. We may also feel that if war automatically means mutual annihilation surely no one would start one. However, as soon as we realize that it is technically and economically possible to alleviate the consequences of a war, then some of these psychological blocks to consideration of additional actions should disappear. The measures suggested by this study are not substitutes for adequate deterrent forces nor for sensible attempts to alleviate tension. They are insurance against the possible failure of these first priority measures and a complement to them.

Our study was not a large effort. It was done by a team of about 20 professionals, drawn from various fields, who worked an average of four months on this problem. We tried to answer or define all the serious questions about nonmilitary defense. Obviously we could not examine these questions in great depth and detail; thus, the numbers the study produced might well change with further investigation. The results, however, are plausible and should be far better than most intuitive feelings and preconceptions about this critical subject.

DESCRIPTION OF THE POSSIBILITIES

Our analysis has brought forth the following results. While it is suggested that these be re-examined by a more complete study, we have sufficient confidence in them to suggest a $500 million program, described later. Roughly we decided that:

There are a number of combinations of military and nonmilitary measures which could provide valuable levels of protection in a nuclear war. The level of protection depends on the size of the program and the nature and magnitude of the attack. Inexpensive measures designed to insure national survival in an all-out war of the early 1960's might be fairly cheap and relatively reliable—something of the order of a billion dollars or a fraction thereof should be sufficient. More complete programs, designed to protect more than the most easily protected people, would be more expensive. Because such programs cost in the tens of billions of dollars, they are automatically controversial. However, we believe that at least the inexpensive programs should be carried out—so that if a war should occur the majority of our population would not only survive the war but would be able to restore some semblance of prewar society quite rapidly. In a war of the early 1970's, even minimum measures to insure survival might be expensive (in the tens of billions) and probably less reliable. (Cost and

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[1] This paper is a revised version of an article, "How Many Can Be Saved," that appeared in the Bulletin of the Atomic Scientists, vol. XV, No. 1, January 1959.

[2] "Report on a Study of Nonmilitary Defense," the Rand Corp. Rept. R–322–RC, July 1, 1958.

performance change with time because the enemy threat changes.) However, at least a start should be made in preparing such measures.

Oversimplifying a bit, one can say that during this 1960–70 period against a premeditated all-out surprise attack, moderate nonmilitary defense programs, if combined with reasonable military programs, should protect about half the population with high confidence, an additional one-fourth with medium confidence, and a final one-fourth with low confidence. A phased program might start with relatively cheap measures for 1960, develop into a minimum fallout program and then possibly later into a quite adequate or "luxurious" program which included blast shelters. While the planning should be done on this basis, there need be no irrevocable commitments to go ahead with the next phase if for any reason it seemed desirable to slow the program down or stop it.

It should be noted that wars can start in a manner other than a premeditated program and then possibly later into a quite adequate or "luxurious" program might be very effective. Therefore, even if we are not willing to pay the cost for complete preparedness, we might be willing to initiate partial programs. These partial programs could be combined with prewar mobilization capabilities designed to put in an adequate program in a few years if the international situation deteriorates. It is plausible to consider such prewar mobilization capabilities because a country with a gross national product of about $500 billion and a construction industry whose capacity is close to $100 billion can contemplate doing things in a hurry if cheap but time-consuming preliminaries such as those involved in research, development, planning, analysis, design, programing, and legal hurdles have been eliminated.

In addition to protecting people from the immediate effects of the war, it is necessary to insure their survival in the postwar environment and then to restore prewar standards of living if possible. Our study also indicated that:

Shelters with long occupancy time and the use of known anti-contamination techniques should make it possible to handle the acute radiation problem (during the first 3 months) from even severe attacks.

With only moderate preparations in the early period and more elaborate ones in the later, it should be possible to handle short-term (3–24 months) survival, patchup, and repair problems.

Combinations of military and nonmilitary measures could protect enough capital to enable the economy to be restored to about half the prewar levels in the first year. The recuperation to prewar levels might be much faster (5–15 years) than has been generally supposed. In any case, if reasonable measures were taken the economy, on a per capita basis, would in all probability not drop below 1930–40 levels, except perhaps in the first postwar year.

Long-lived radioactivity problems, while serious, could be alleviated to the extent that, in comparison with the direct effects of the war, they would have a relatively minor impact on the economy or personal life of the population. Subject to uncertainties, the same should be true of the genetic effects. Even though these may last for a thousand years, the burden on any single generation should only be a fractional increase over the current normal burden of congenital defects.

IMPLICATIONS FOR DETERRENCE

U.S. national policy rests on a deterrent strategy. Presumably, deterrence of Soviet attack depends upon Soviet calculations of their risks versus their chances of success. Our study distinguishes three types of deterrence in examining the implications of nonmilitary defense:

Type I—Deterrence of a direct attack on the United States. In this case any calculation the Soviets might make would assume they have the first strike and the United States strikes back with a damaged force. (Calculations ignoring the effects of the first strike and therefore based on the preattack inventory of forces can be very misleading.) The Soviets then ask themselves what damage they are likely to suffer before hostilities end. Here the Soviet Union's estimate of the effectiveness of their passive defense preparations may play a crucial role, and the United States should examine these to see what questions they raise. Presumably since the Soviets can count on warning, and because they need only defend themselves against a damaged force, even moderate preparations might be considered effective under some circumstances. It is not that the Soviets could reliably expect to be untouched, but that a situation might arise in which the Soviets might feel that going to war was the least risky of the available alternatives.

U.S. nonmilitary defense programs will probably have only a marginal effect on U.S. type I deterrence. Because the war will almost undoubtedly be short and fought with existing stocks, civilian production and morale are unimportant to the military course of events. The chief importance of U.S. nonmilitary defense in this case resides in more or less accidental byproducts such as protected communications, survival of off-duty personnel, greater ability to improvise and augment SAC-type forces for second and later strikes, and possibly most important of all, a resistance to post-attack blackmail tactics which might otherwise succeede in at least partially disarming our surviving SAC forces.

. Type II—Deterrence of extremely provocative behavior. The Soviets now ask themselves if they can force the United States to accept peacefully the consequences of some extremely provocative action (say a large-scale attack on Europe or a Munich-type crisis). They presumably ask themselves, "What is the U.S. risk-gain calculation?"—crediting the United States with the first strike. Under these circumstances, in which there has been a tense situation, the Soviet Union strikes second with a damaged force; and when U.S. warning problems have been simplified, even modest civil defense programs relying mainly on evacuation and improvisation might perform impressively enough to make it clear to the Soviet planner and to our allies that there is a good possibility, if not a certainty, that the United States would not accept the provocation peacefully. If the Soviets were not deterred then the United States might actually carry out an evacuation to try to persuade them to desist. If the evacuation did not persuade the Soviets to desist, then in the last resort the United States might decide that it was less risky to go to war than to acquiesce.

The ability and willingness of the United States to engage in type II deterrence activities will be strongly affected by our type I deterrence capabilities. Because using type II deterrence automatically strains our type I deterrence (particularly if we try the evacuation maneuvers), we now need more of it. Almost all of the remarks made about type II deterrence carry over to our ability to wage and limit "limited wars."

Type II deterrence is, of course, symmetrical. There is an enormous difference in the bargaining ability of a country which can, for example, put its people in a place of safety on 24 hours' notice, and one which cannot. If it is hard for the reader to visualize this, let him imagine a situation where the Russians had prepared for exactly that and we had not. Then let him ask himself how he thinks we would come out at a subsequent Munich-type conference.

Type III—Deterrence of moderately provocative actions. In this case it would be wishful thinking to expect deterrence to work most of the time. However, Soviet calculations which contemplate provoking the United States might be influenced by the existence of a U.S. plan for a crash nonmilitary defense program. If a Soviet provocation touched off such a U.S. program, then the Soviets would probably be forced either to match this program, accept a position of inferiority, or possibly even strike immediately. In all cases, the costs and risks to them of their provocation are increased. If this possibility is made clear and probable, the Soviets should include these costs and risks in their calculations. Our type III deterrence is also affected by Soviet nonmilitary defense programs because their willingness to be aggressive and their bargaining ability may be influenced by the risks they run.

A converse effect may be an important additional bonus of even a modest start toward a realistic U.S. civil defense program. Such a program makes more "rational" a strong foreign policy (when a strong foreign policy might seem desirable) by decreasing the immediate risks. Making a stronger foreign policy more "rational" may or may not make it more probable, but at least it is made more credible. This should help in deterring some minor as well as extreme provocations. Even an explicit mobilization capability can be important because it should make it credible to our allies that we will at least be able to put ourselves soon into a position where we can rationally back them.

IMPACT ON MILITARY MISSIONS

The study made a superficial investigation of the components of nonmilitary defense and their relationship to complete and balanced defense and deterrence systems. For example, nonmilitary defense provides a new perspective for studies of active air defense and offense. Most air defense studies have tried to devise systems to protect the U.S. mobilization base—economic resources and population—with a high level of certainty. Actually, this goal can be made to seem attainable only if unrealistically optimistic assumptions are made. The result is either a dangerous over-optimism about the power of defense or an equally dangerous apathy and despair. Similar remarks can be made about our strategic offense insofar as it is designed only to deter and not to fight a war. Such viewpoints tend to ignore the very important role our defense and offense systems can have between these two extremes in alleviating the consequences of war.

Because a nuclear war would be horrible, it takes an act of imagination to visualize one starting; but it should not take a further act of imagination to believe that such a war would end. As part of the study we considered various ways in which a war might terminate. If one or both sides were improperly prepared, such a war might end in a few hours by the almost total destruction of the military forces of one side by the other. If, however, both sides had made even moderate (but realistic) preparations to fight a long war—a war of at least a few days duration—then appreciably military forces should be left on both sides after the initial onslaught. And this in turn means that there are advantages to both sides in ending the war by negotiation.

Certain tactics facilitate a quick and favorable end by negotiation. For example, one side can avoid some large fraction of the other side's cities and use the threat of destruction of these cities both as a hostage for the enemy's good behavior and as an inducement to negotiate. Similarly, the other side can adopt a similar tactic and use the threat of his surviving forces to compel the enemy to offer "reasonable" terms. As in classical warfare, the "reserves" may play a central role.

No matter what sequence of events is imagined, the possibility that the offense and defense could survive for some days is important. Nevertheless, most discussions of new strategic systems appear overly concerned with wars that last less than 1 day. If we are seriously interested in alleviating the consequences of a war, then we are interested in having military capabilities—both offensive and defensive—on the second and third days of the war. In fact, sensible military planning would provide for wars lasting from 2 to 30 days, though the first day—or even hours—of the war is still likely to be of the utmost significance.

INTERACTIONS WITH DISARMAMENT

The most obvious effect of civil defense on disarmament is the reduction in the vulnerability of the civilian targets. This has only an indirect effect on the military situation of a potential defender since most civilians and their buildings are not really military targets. However, a reduction in civilian vulnerability may be of major importance in reducing the risk that a potential aggressor faces. Presumably he can contemplate accepting a larger retaliatory strike if he has a reasonable nonmilitary defense program than he could if he didn't have one. To this extent a civil defense program conflicts with some of the objectives of a disarmament program.

There are, however, two very important ways in which civil defense programs may help a disarmament program. First, the civil defense programs make a nation somewhat less vulnerable to blackmail or a breakdown of the disarmament agreement. If a nation is totally vulnerable to an attack, then it is also totally vulnerable to blackmail and the fact that it might be able to destroy the blackmailing nation does not necessarily help. It is just not credible that a nation such as the United States will consciously and deliberately choose suicide while there is any hope of life. In other words, pure disarmament programs without any civil defense make no allowance for type II or type III deterrence. It is extremely wishful thinking to believe that such things will never be necessary. It may be positively dangerous deliberately to weaken our type II or type III deterrence to the point where it is an invitation to a potential aggressor. Furthermore, even a disarmament program will not completely exclude the possibility of accidental or unpremeditated war. Finally, even the best disarmament agreement might be repudiated or violated—possibly initiating a sequence of events which lead to war. It is, therefore, always necessary either to have capabilities to alleviate the consequences of a war or at least to be able to create capabilities in a short period of time. In general, adequate civil defense capabilities cannot be created in a short period of time unless extensive preparations have been made.

A rather important and valuable effect of a realistic civil defense program (and one that is often overlooked) is a psychological one. If one is designing his military establishment to terminate a war, rather than just to deter one (by punishing the enemy with a retaliatory strike), one is much less likely to indulge in wishful thinking. Even today, without any disarmament schemes, Western military organizations and their governments have psychological and motivational difficulties in maintaining a high operating state of readiness and adequate combat capabilities. This is partly because many feel both that such weapon systems will never be used, and that if they were used they would be so destructive that you don't really care if they operate well or badly. If this attitude is combined with the moral onus on military preparations and planning that a disarmament agreement might bring one could almost confidently predict an undue and possibly dangerous degradation of Western military capabilities. If one is emotionally committed to the belief that deterrence is foolproof, there is not much of a step from being satisfied with a system which is objectively capable of destroying the enemy in a rataliatory blow to a system which can only hurt the enemy, and from there to a system which might hurt the enemy, and finally to one for which there are circumstances in which it is conceivable that the enemy will be hurt. The capacity of Western governments and peoples, under propitious circumstances, to indulge in wishful thinking in the military field is almost unlimited. An official aim which calls for an objective capability to terminate a war in a reasonably satisfactory fashion might have a salutary effect in restraining fancies. (W. W. Marseille has suggested to the author that "this is putting the cart before the horse. The psychological factors are what cause us not to have a realistic civil defense program in the first place." However, the author has found—to his surprise—that once people start thinking in terms of alleviating a war it is possible to successfully make points which it should have been possible to make if one were only arguing deterrence, but which were not taken seriously in this latter context.)

A PROPOSED CIVIL DEFENSE PROGRAM[3]

Once one accepts the proposition that it is possible to alleviate, to some extent, the consequences of a thermonuclear war, one is faced with the question, "Is it worth spending money on such a capability?"[3]

1. The creation of incomplete but worthwhile capabilities by reorienting and strengthening the current civil defense program utilizing feasible evacuation measures, improvised fallout protection, damage control, modest preparations for recuperation and, giving these other measures, the institution of a vigorous program of education and technical assistance to private parties and organizations. Some inexpensive measures might save from 20 to 50 million lives, limit the contingent damage to property, markedly facilitate our ability to recuperate, and provide an environment in which private citizens could do sensible things on their own to increase their chances of survival.
2. Research and development on all important aspects of the art of nonmilitary defense. Unlike research and development on military matters, nonmilitary defense has received comparatively little money and effort. In particular, the little work necessary for this study indicated that imaginative work could not only result in large improvements in the effectiveness of defense measures, but could also uncover many unsuspected problems that would otherwise be very unpleasant surprises.
3. Accompanying the research and development work should be a vigorous effort on the systems design of various combinations of military and nonmilitary defense. This effort should produce specification, including phasing, of many alternative programs. These specifications should be of sufficient detail to permit their costing and their performances to be caluculated over time and under many circumstances. Paper planning and design should be undertaken for a number of the alternatives specified so that any program finally adopted

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[3] Most of the material in this section came from the Rand Corp. Report RM2206–RC, "Some Specific Suggestions for Getting Early Nonmilitary Defense Capabilities and Initiating Long-Range Programs," by Herman Kahn et al. That report was originally prepared in the early part of 1958, and was circulated in a limited fashion to various individuals for information and comment. While I have made some minor modifications in the material to correspond to some changes in my viewpoint, there has been no thoroughgoing revision. The dollar recommendations should be thought of as quantitative expressions of intuitive judgments. However, I should also note that I probably have substantially more justification for my estimates than do many official proposals. In any case, these things are so uncertain, and for reasonable programs the overall performance variations with minor changes in allocations are so small, that as citizen, voter, and taxpayer I am prepared to defend the numerical recommendations, even if as an analyst I have to concede that there is incomplete documentation.

would be less costly and have its leadtime reduced (by perhaps 3 to 5 years over conventional methods of proceeding).

4. While it is technically feasible to start a large-scale program of nonmilitary defense now, there are many uncertainties and gaps in our knowledge. After objectives 2 and 3 (research and development and leadtime reducing measures) have been accomplished, the proper balance between military and nonmilitary expenditures can be studied. The Government could then make wiser decisions, and some of the difficulties resulting from a combination of ignorance and uncertainty would be eliminated or decreased. The decision to go ahead or not go ahead with a multi-billion-dollar program should not be made until objectives 2 and 3 have been carried out.

5. There seem to be many possibilities for inexpensive preparatory actions that could result in the creation of important capabilities in the 1965–70 time period. Again, irrespective of any decision to go or not go into a multi-billion-dollar program, these possibilities should be studied; if and when such actions are found desirable they should be put into practice.

A possible allocation for the additional $500 million to be spent on civil defense might go as follows: (This was what Kennedy did in 1961.)

1. Radiation meters	[1] $100,000,000
2. Utilization of existing structures for fallout protection	[1] 150,000,000
3. Preliminary phase (including research and development) of a spectrum of shelter programs	75,000,000
4. Movement, damage control, and anticontamination, etc	[1] 75,000,000
5. Systems studies and planning	20,000,000
6. Other research and development	20,000,000
7. Prototype shelters	20,000,000
8. Education and technical assistance	20,000,000
9. Miscellaneous	20,000,000
Total	[1] 500,000,000

[1] Indicates Federal expenditures that would likely be supplemented by non-Federal expenditures stimulated by the program.

The above program can be divided into two parts: a short- and a long-range program, though there is a lot of overlap and joint use in the two programs, which is the reason why we do not budget them separately.

About 60 to 70 percent of the above $500 million would be spent to purchase capabilities that would be useful if a war started in the immediate future. Because the possible gains are so large, I do not believe that it is necessary to justify spending such a relatively small sum of money, even though there are some uncertainties about the performance of the program. The sum of $300 million is very small if it can make the difference between a relatively expeditious recovery for the survivors of a war and one that might not only be slow but could conceivably not occur at all; or if it could buy the kinds of capabilities that would make the difference between the Russians being able or not being able to blackmail us.

About 30 to 40 percent of the $500 million in our proposed budget, or less than $200 million, is allocated to research analysis, development, planning, and design for a spectrum of civil defense programs. This may seem to be a great deal of money to spend on producing pieces of paper and prototypes. But I believe that $200 million is a reasonable sum of money to spend on finding out how best to secure the lives and property of the Nation, and I would regard the proposed research program as a mandatory precondition to the decision to spend or not spend any large sums on passive defense itself.

Is $200 million really an unreasonably large sum? It costs from $50 to $100 million to develop an engine for a military airplane. It costs $100 to $200 million to develop an interceptor aircraft and $500 million to $1 billion to develop an intercontinental bomber. The ICBM development program cost between $1 and $2 billion. The Department of Defense spends $5 billion every year on research and development. We are saying that a complete nonmilitary defense program is at least as complicated as an interceptor aircraft.

We should also ask if $200 million is too little to be spending on long-range programs. Some people suggest the immediate initiation of large-scale passive defense programs that would cost in the neighborhood of $25 billion. It is improbable that very large sums could be spent efficiently on construction in the next year or two, and it is almost certain that if the attempt were made without a prior program of the sort we are suggesting that not only would the wrong sorts of personal protection be procured, but there would also be major, maybe disastrous, inadequacies and lacunæ in the overall program.

We should consider the initiation of some inexpensive measures during the course of, and based on the results of, the research program. For example, circumstances might suggest a large "Starter Set"—including procurement of such materials as appear most likely to cause bottlenecks in a larger program: reinforcing steel, corrugated steel, structural steel, cement, and other building materials. If this were done, there would be no lag in the completion date of even the largest programs even though no major construction were begun immediately.

A decision to go ahead or not go ahead on a multibillion-dollar program should be made sepaartely from and subsequent to the completion of the proposed $200 million research program.

Still addressing ourselves for the moment to the proponents of large programs, there is at least one good reason why the Government may now be loathe to make a commitment for shelters. The shelter program itself has been looked at in only a superficial way, and many of the other problems associated with preserving a civilization and a standard of living have not been looked at even superficially. While our study tried to look at these overall problems and, in particular, to ask the question, "How does the country look 5 or 10 years after the war as a function of our preparations?" we scarcely scratched the surface. We believe we have shown that it is plausible, at least in the immediate future, that with inexpensive measures the United States could be an acceptable place to live even a year after the war. However, we concede that the uncertainties are large enough to raise the question of sheer survival, and the problem gets more severe in the later time period. Until the feasibility of recovery and other long-term problems and their solution are settled, it will be hard to arouse real interest in attempts to alleviate the consequences of war. But it is possible to settle these questions relatively inexpensively and at the same time avoid delaying the completion date for a full program or the immediate acquisition of moderate capabilities. The $200 million of our civil defense budget should be spent over a period of 2 or 3 years on what might be called the "cheap" starter set—the preliminary phases of a civil defense program—mostly on research, development, analysis, planning, and design.

These preliminaries should not be restricted to any prechosen program. The scale of the final program will presumably be determined by the results of these investigations and the current international situation; it should not be fixed prematurely. It is also most important to consider explicitly time period in the late sixties and early seventies. Unless we start soon the long-range programs needed to ameliorate the effects of potentially very destructive attacks of this time period, we will find that we have irrevocably lost very valuable opportunities.

Our goal in allocating funds to projects was not that every dollar be spent economically, but rather to make sure that every subject be covered adequately. While we were generous, we tried to refrain from padding. Although our figure of $200 million is, of course, only approximate, it is as likely to be low as high if an adequate job of research, development, systems analysis, planning, and design is to be undertaken. Many of the potential civil defense programs are so expensive that it is worthwhile to spend some money speculatively if there is any chance at all of the overall program being helped by even a small percentage. Therefore, the aim should not be to see that every dime is spent on the assurance that it will result in a successful project, but rather to see that all interesting avenues are explored. Otherwise, there may be disastrous inadequacies or even complete lacunae in the program that is finally adopted.

Such a large and many-sided program of study, planning, and innovation require a strong monitoring effort of a sort that is not common in most Government agencies. This effort has to be much more than the ordinary R. & D. administration. The monitors must maintain a continuous and close observation of all the programs and constantly evaluate their direction and results. While they should be able to suggest the termination of fruitless programs, their main purpose should be to encourage the expansion of promising effort. Most important, they must be alert to identify gaps and inadequacies in the programs, and suggest remedial action.

Because of their crucial role, the monitors must obviously be an exceptionally competent and well-informed group of people. However, the monitors do not need and should not have the authority to orient all programs toward predetermined objectives. Experience has shown that attempts to conduct large and overcoordinated programs tend to create inflexibility and to stifle new, unproven ideas or independent approaches. Hence, the monitors should act as an advisory group rather than as a "research czar." But they must have the authority to make suggestions and offer criticism at all levels and have the right to contact the researchers or planners in the field.

The monitoring group could be located in the independent long-range planning organization, mentioned in chapter 2, part II, and act for the various Government agencies that will be principally concerned with the nonmilitary defense effort. Or, it could be a special group in OCDM or under the Presidential assistant for national security affairs. In order to maintain a good "feel" for the program as a whole and to foresee future requirements, the monitors should be closely associated with the systems analysis and operations research program. Perhaps they should also have direct access to funds for small studies or pilot projects.

THE FULL PROGRAM

A superficial description of the $500 million program follows. Somewhat more detail (of a very similar program) can be found in the previously mentioned Rand Corp. report, RM 2206–RC.

1. *Radiation meters ($100 million)*

Our program calls for 2 million dose-rate meters (at about $20 a meter), 10 million self-reading dosimeters (at about $5 a meter, including an allowance for chargers), and 20 to 50 million dosimeters (at about $1 to $2 a meter).

Only a portion of the meters would be distributed before hostilities. The rest would not be distributed until a "national emergency" occurred or until the postattack period, and they should be stored with this in mind. The final distribution of meters might go somewhat as follows: 500,000 dose-rate or survey meters to the large shelters (capable of sheltering more than, say, 50 persons); 1 million to outdoor workers of various types, such as farmers, prospectors, foresters, construction workers, and so on; 250,000 to individuals and organizations in various towns and cities;[4] and 250,000 to the working teams discussed below under item 4.

The self-reading dosimeters would be distributed approximately as follows: 2,500,000 to the work parties discussed under 4 below; 2,500,000 to the shelters, schools, and other places; and 5 million to the people who work out-of-doors in possibly uncontrolled environments. The $1 and $2 dosimeters would be issued to everybody who is in an even moderately hot area and is not working under completely controlled conditions. The total budget allocated above is more than $100 million, but we think the number of meters suggested could be obtained and distributed if the Government were to allocate only $100 million. The rest of the budget should be made up of stimulated expenditures for meters by local governments, private groups, and individuals.

2. *Utilization of existing structures for fallout protection ($150 million)*

We would expect about $50 million to be spent on identifying, counting, and labeling the various structures that either provide valuable levels of fallout protection as they now stand or that can easily be modified to do so. The rest of the money would be spent for such supplies as radios, minimal toilet equipment (such things as primitive as buckets), and possibly even minimum food supplies (candy bars, multipurpose foods and such), or materials for improving the protection of the shelter. The survey should include places that can be used as improvised fallout shelters with various amounts of advance warning—1 hour, 2 hours, 4 hours, 8 hours, 16 hours, 2 days, 2 weeks, and even longer. We should hope to get detailed plans for the different kinds of improvisations that are pissible as a function of the time which is available.

3. *Preliminary phase (including research and development) of a spectrum of shelter programs ($75 million)*

One of the most short-sighted things that OCDM has done is to reduce its expenditures on the study of blast shelters—just because it is not part of the current "national shelter policy" to have blast shelters. As I have tried to stress in these lectures, we just do not know today what we will want 5 or 10 years from now, and current programs and requirements should not overinfluence

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[4] Something like this is being done by OCDM.

current research and development. We should not prejudge these unknown future desires of ours by not undertaking inexpensive preliminary work on many more things than we expect to procure. It is only by having a broad base of research and development that we can expected to understand our problems and be in a position to have a flexible procurement policy.

These last remarks have special point for research and development and even preliminary programing in the shelter field. It is clear that if the international situation had already deteriorated to the point where we felt there was a high probability that we would have to fight a war, we would be instituting a very luxurious shelter system, indeed. It may turn out that, given the possibilities for weapons development, a pure fallout system will not be adequate in the late sixties and early seventies. For these and other reasons, the shelter studies should investigate the many different levels of protection that would be compatible with programs of as low as $2 or $3 billion to programs as high as $200 billion.

A possible allocation for the $75 million we have allotted to shelters would be as follows:

Theoretical work in the response of structures	$1, 000, 000
Theoretical work in design	1, 000, 000
Basic designs	3, 000, 000
Experimental testing	15, 000, 000
Detailed study of:	
10 large cities	10, 000, 000
10 medium cities	5, 000, 000
10 towns and rural areas	5, 000, 000
Study of geology and underground possibilities	10, 000, 000
Study of nonpersonnel shelters	10, 000, 000
Special equipment	10, 000, 000
Miscellaneous	5, 000, 000
Total	75, 000, 000

4. Movement, damage control, anticontamination ($75 million)

The two main things we should hope to provide under this category are the capability to evacuate to improvised protection and the creation of a core of "reservists" that would be organized to facilitate the evacuation, the improvisation of shelters either pre- or post-attack, and that would also be useful in the immediate postattack and longer run rescue, decontamination, debris clearing, continuity of government, housing, and repair problems. There are at least 5 million people in the United States who have the proper skills for such work. We should sign up 200,000 of these people as part-time but paid cadres and many others as unpaid part-time cadres or just available volunteers. The 200,000 people might go through a 1-week or 2-week training course every year. In wartime, or in a tense preattack situation, we should plan to expand them by a factor of 5 to 20. Such an organization would probably cost about $500 per man per year, or about $100 million per year for 200,000 people. However, it would be practically impossible to spend more than $25 to $50 million in the first year or two when this group is being organized, and this is the amount in our budget. This cadre might be supplemented (or replaced) by the military reserves.

Another $25 to $50 million would go for all the measures that are needed to create different kinds of potentially useful evacuation capabilities. What money is left, probably around $10 to $30 million, would be used to study and implement the damage control measures that will be necessary to limit the bonus damage when cities, factories, and homes are abandoned, to control fires, and to provide some additional protection for some government or crucial commercial stocks. This last figure is very definitely an allotment and not an estimate.

5. Systems studies and planning ($20 million)

The program described to this point is composed mainly of interim measures that are intended to fill the gap until we can decide what our long-range plans should be.

Among the first things to be studied and planned for are the different kinds of nonmilitary defense systems needed for various situations, and how we can build in our programs large degrees of flexibility. We must design systems to be in a position to exploit favorable circumstances and to hedge against unfavorable ones. Probably the worst defect of civil defense planning today is that it tends to concentrate on a single set of assumptions and circumstances (a surprise attack directed at civilians), a set that also happens to be the most difficult to handle. As a result, civil defense recommendations have not been tested against a large number of possibilities. The proposed plans should not only consider a large range of circumstances, they should also consider phasing problems so that we will get early capabilities and still be able to accommodate growth in the future—particularly growth required by either unexpectedly large threats or higher standards. Some of the situations that might be studied are listed below:

(*a*) Movement of the population to shelters, considering warnings of minutes, 1 to 3 hours, 10 to 20 hours, and strategic evacuation.

(*b*) The various attack-response patterns (suggested in the lectures).

(*c*) Enemy tactics corresponding to three possible enemy target objectives: military, population, and recuperation—or mixtures of these.

(*d*) Civil defense postures as influenced or determined by many things, including variations in our own or enemy objectives, budget levels and allocations, disarmament, degrees of tension, changes in NATO, Chinese developments, other Russian satellite developments, and so on.

(*e*) Other strategic and tactical considerations; for example, sneak attacks and other unconventional tactics, unconventional weapons, reattacks, and various ways that war can be terminated.

(*f*) Worldwide planning.

(*g*) Basic technical uncertainties to be studied and allowed for include the performance and effects of weapons, carriers, air defense systems, medical unknowns, and so on.

In addition, all studies should be conducted with an eye to understanding and exploiting interactions between military and nonmilitary defenses. Some areas in which these interactions occur, and some proposed research projects, are listed below:

(*a*) The circumstances in which wars can start should be examined to determine what roles can be played by augmentation abilities brought into play in tense situations, on D-day, or even after D-day. For the starter set our military prewar mobilization capability is important. Lastly, and most important, we must reexamine our capability of fighting for days or weeks.

(*b*) Civil defense contributes to the overall problem by reducing the job of air defense and air offense to manageable proportions: by making large military budgets more acceptable (fighting and winning a war takes more military power than is needed for pure deterrence); by making safer use of nuclear weapons in air defense; and by protecting important elements of our air defense and air offense capabilities.

(*c*) On the military side, air defense provides warning, increases the enemy's raid-size requirements (even for minimum-objective attacks), forces him to use expensive carriers and tactics, cuts down his force, decreases his bombing accuracy, and may provide time against ICBM attacks by killing the first few missiles so people can get into shelters.

(*d*) Air offense (and effective civil defense) forces the enemy to buy expensive defenses (by making a U.S. first-strike credible), draws his attacks (particularly his first strike) away from population and recuperation targets, ends the war quickly either by destroying the enemy or forcing him to negotiate, and complicates the enemy's job by being dispersed, hard, and alert.

It might be appropriate at this point to comment on some of the characteristics of good analyses and plans. The following is quoted from RM-1829[5] "Techniques of Systems Analysis," by Herman Kahn and Irwin Mann.

"An item of equipment cannot be fully analyzed in isolation; frequently its interaction with the entire environment, including other equipment, has to be considered. The art of systems analysis is born of this fact; systems demand analysis as systems.

"Systems are analyzed with the intention of describing, evaluating, improving, and comparing with other systems. In the early days many people naively thought that this last meant picking a single definite quantitative measure of effectiveness, finding a best set of assumptions, and then using modern mathematics and high speed computers to carry out the computations. Often their professional bias led them to believe that the central issues revolved around what kind of mathematics to use and how to use the computer.

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[5] A Rand Corp. report.

"With some exceptions, the early picture was illusory. First, there is the trivial point that even modern techniques are not usually powerful enough to treat even simple practical problems without great simplification and idealization. The ability and knowledge necessary to do this simplification and idealization is not always standard equipment of scientists and mathematicians or even of their practical military collaborators.

"Much more important, the concept of a simple optimizing calculation ignores the central role of uncertainty. The uncertainty arises not only because we do not actually know what we have (much less what the enemy has) or what is going to happen, but also because we cannot agree on what we are trying to do.

"In practice, three kinds of uncertainty can be distinguished:

"1. Statistical uncertainty.
"2. Real uncertainty.
"3. Uncertainty about the enemy's actions.

"We will mention each of these uncertainties in turn.

"*Statistical uncertainty.*—This is the kind of uncertainty that pertains to fluctuation phenomena and random variables. It is the uncertainty associated with 'honest' gambling devices. There are almost no conceptual difficulties in treating it—it merely makes the problems computationally more complicated.

"*Real uncertainty.*—This is the uncertainty that arises from the fact that people believe different assumptions, have different tastes (and therefore objectives), and are, more often than not, ignorant. It has been argued by scholars that any single individual can, perhaps, treat this uncertainty as being identical to the statistical uncertainty mentioned above, but it is in general impossible for a group to do this in any satisfactory way.[6] For example, it is possible for individuals to assign subjectively evaluated numbers to such things as the probability of war or the probability of success of a research program, but there is typically no way of getting a useful consensus on these numbers. Usually, the best that can be done is to set limits between which most reasonable people agree the probabilities lie.

"The fact that people have different objectives has almost the same conceptual effect on the design of a socially satisfactory system as the disagreement about empirical assumptions. People value differently, for example, deterring a war as opposed to winning it, or alleviating its consequences if deterrence fails; they ascribe different values to human lives (some even differentiate between different categories of human lives, such as civilian and military, or friendly, neutral, and enemy), future preparedness versus present, preparedness versus current standard of living, aggressive versus defensive policies, etc. Our category, 'real uncertainty,' covers differences in objectives as well as differences in assumptions.

"The treatment of real uncertainty is somewhat controversial, but we believe actually fairly well understood practically. It is handled mainly by what we call contingency design

"*Uncertainty due to enemy reaction.*—This uncertainty is a curious and baffling mixture of statistical and real uncertainty, complicated by the fact that we are playing a non-zero-sum game.[7] It is often very difficult to treat satisfactorily. A reasonable guiding principle seems to be (at least for a rich country), to compromise designs so as to be prepared for the possibility that the enemy is bright, knowledgeable, and malevolent, and yet be able to exploit the situation if the enemy fails in any of these qualities.

"To be specific:

"To assume that the enemy is bright means giving him the freedom (for the purpose of analysis) to use the resources he has in the way that is best for him, even if you do not think he is smart enough to do so.

"To assume that he is knowledgeable means giving the enemy credit for knowing your weaknesses if he could have found out about them by using reasonable effort. You should be willing to do this even though you yourself have just learned about these weaknesses.

"To assume that the enemy is malevolent means that you will at least look at the case where the enemy does what is worst for you, even though it may

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[6] "The Foundations of Statistics," by L. J. Savage; "Social Choice and Individual Values," by K. J. Arrow.

[7] The terminology "non-zero-sum game," refers to any conflict situation where there are gains to be achieved if the contenders cooperate. Among other things, this introduces the possibilities of implicit or explicit bargaining between the two contenders. The whole concept of deterrence comes out of the notion that the game we are playing with Russia is non-zero-sum.

not be rational for him to do this. This is sometimes an awful prospect and, in addition, plainly pessimistic, so one may wish to design against a 'rational' rather than a malevolent enemy; but as much as possible, one should carry some insurance against the latter possibility."

6. Other research and development ($20 million)

This is for miscellaneous research in the medical, biological, food, agricultural, anti-contamination, and fallout areas. The AEC currently spends about the allotted sum every year to study the inherently simpler problem of peacetime fallout from tests. The equally important special wartime problems are mostly being neglected.

7. Prototype shelters ($20 million)

We would suggest building about 10 million dollars' worth of large shelters which, if economically feasible, might include some peacetime functions. In addition to "customary" shelters, this program should include more elaborate shelters and high overpressure shelters. The other $10 million should go for private family-type shelters, running an average of, say, $1,000 apiece. This should enable us to build 10,000 shelters, or 1 for every 20,000 people. This means that every town in the United States would have at least one prototype shelter.

8. Education and technical assistance ($25 million)

It is one of the major objectives of the above program to create an environment in which private citizens and organizations can do sensible things on their own. The main way the Government can encourage this is to do enough on its own so that people will see that if they supplement the Government's efforts they will either improve their chances for survival or the style in which they survive. Many of the preceding suggestions are aimed at making it possible for the Government to furnish realistic technical information and planning assumptions. This will enable those that wish to, to do sensible things on their own.

We feel that at least part of the present apathy in the United States is due to ignorance of what can be done or to doubt that anything can be done. This apathy is intensified by the inadequacy of official pamphlets. The problem does not result from security restrictions or inadequate releases of information; official studies themselves are inadequate. Better studies and more definitive Government programs are needed. Realistic long-range planning, such as we are proposing, would go far toward restoring public confidence in the merits of Government plans and suggestions. Even more effectively, the institution of the "cheap" program, which depends mainly on improvised fallout shelters, would encourage many to build more adequate shelters on their own. As long as there is no reasonable overall program, few will undertake private actions.

In addition to general information, the Government should offer to share some of the private expenses. However, because of the small size of the program, the Government should not contribute anything toward private projects unless it gets a great deal of leverage for its money. One of the easiest ways to get such leverage would be for the Government to spend small sums of money on the preliminary phases of the private projects; that is, it should be willing to go to a private company with a complete set of blueprints showing that company what it would have to do if it participated in a serious way in such a program. This would enable the company, without spending any of its own money or much energy, to get very specific ideas of the cost and performance of its own program. It would help eliminate the inertia that might otherwise prevent companies from initiating any actions. The Government should do similar things for private persons, not only by furnishing complete blueprints for either the modification of existing buildings or for the incorporation of protection in new buildings but also by offering technical assistance in their construction. It should also furnish services to architects, engineers, and others.

In addition to helping private companies and individuals, the Government should try to elicit as much help from the nongovernmental part of our society as it can. For example, once the research program has provided some indication of what a reasonable passive defense program should involve, the Government should enlist the help of private professional groups to expedite some of the necessary intellectual and technical developments. Some of the organizations whose aid might be solicited include:

American Society for Civil Engineers.
American Concrete Institute.
American Bar Association.
American Medical Association.
American Institute of Architects.
National Planning Association.
Committee for Economic Development.
Chambers of commerce.
National Bureau of Economic Research.
American Association of Railroads.
American Society for Testing of Materials.
American Society for Mechanical Engineers.
American Society for Electrical Engineers.
American Society for Heating and Ventilating.
National Association of Manufacturers.

In the past, private groups have sometimes put time and energy into studies for the Government, but a lack of adequate orientation has often meant that their studies were obsolete before they were started. It is important, both for the morale of the participants and the usefulness of their product, that realistic environments and planning assumptions be given to such groups. For example, the American Society of Civil Engineers (ASCE) is reported to be considering a standard for the protection of buildings in large cities on the order of 5 to 10 pounds per square inch. Such buildings might not be useless in some situations, but they would certainly be useless if bombs dropped nearby. We would propose that a much more useful activity for the ASCE would be to look at joint-use, blast-resistant construction for small cities and rural areas rather than for large cities. An even more useful thing, and one which we would urge be done with a high priority, would be to look at the possibilities for joint-use fallout protection, both with and without warning (hours or days). For example, buildings might be built to use sandbags or fillable shutters that could be put up at the last moment. Either of these would greatly decrease their vulnerability to radiation. We feel that the possibilities are so promising that an appreciable portion of an expensive fallout program might be saved (though only a portion). It is clear there are many other examples where private organizations could be useful. Universities and foundations, for example, could make major contributions.

It is with some reluctance that I include education in the program. This is not because education is not a very important thing. In particular, in a program that depends a great deal on improvising existing assets, it is probably very important for many people to understand reasonably well what they should do. However, the Government has a tendency to try to depend upon education and paper plans to do everything, rather than to spend even small sums for capabilities that would make the educational program realistic and useful. It is not going to be true that our society can be preserved in a war by individual action supplemented only by Government pamphlets and paper plans. I suspect that the major educational impact will come, not from the formal program of information or propaganda, but simply from the impact of the Government's allotting reasonably large resources to a program that it is willing to defend intellectually. This alone should make many people understand that the program is a serious effort and that one does not have to be a "crackpot" or "wishful thinker" to join in. Conversely, if the Government tries to accomplish this program by education alone, if it is unwilling itself to invest a few hundred million dollars and thereby shows that it has little confidence in the effort, then, I think, we should not be surprised if the program fails completely.

It may, of course, turn out that the Government does not wish to engage in a program as ambitious as the one described, modest as it may seem to those of us in the planning field. In that case, we suggest that the Government try at least the following:

1. Reorient Government planning, both military and nonmilitary, to the proper kind of short and long wars; in particular, make explicit preparations for improvising preattack and postattack capabilities.
2. Reorient current stockpile programs to contribute to postwar survival recuperation.
3. Reorient and strengthen civil defense programs to pay particular attention to those situations in which their capability is most applicable rather than try to handle all problems across the board.

4. Broaden the current programs of research, development, and systems analysis to consider in more detail the problems involved in recuperation and in the postwar period generally.
5. Study and propose legislation now to facilitate postwar economic stabilization and recuperation.
6. Initiate research and study in the use of mines as personnel and industrial shelters.
7. Initiate a program of technical education and assistance to orient and encourage private actions planning and research.
8. Do much more long-range planning in the field of nonmilitary defense and independent and dependent groups. In particular, we suggest that OCDM or the executive department establish a permanent long-range planning organization of the same type as Rand, ORO, or the like.

THREE LECTURES ON THERMONUCLEAR WAR (1960–75) BY HERMAN KAHN

LECTURE I. THE NATURE AND IMPACT OF VARIOUS KINDS OF THERMONUCLEAR WARS

This lecture asks the question, "Is it really true that only an insane man would initiate a thermonuclear war or are there circumstances in which the leaders of a country might rationally decide that war is preferable to any of its alternatives?"

It is concluded that there are plausible, even probable, circumstances in which a country may rationally decide on war as its best alternative. In arriving at this conclusion it is convenient to examine eight distinct phases of a thermonuclear war.

1. Various phased programs for deterrence and defense and their relations to foreign policy.
2. Wartime performance with different preattack and attack conditions.
3. The acute fallout problems.
4. Survival and patchup.
5. Maintenance of economic momentum.
6. Long-term recuperation.
7. Long-term medical problems.
8. Genetic problems.

LECTURE II. THE FORMULATION AND TESTING OF STRATEGIC OBJECTIVES AND WAR PLANS

This lecture asks such questions as, "Why and how might a thermonuclear war be initiated? How might it be fought and terminated?"

In discussing these questions it is desirable to distinguish at least three kinds of deterrence:

Type I—The deterrence of direct attack (passive deterrence)
Type II—The deterrence of extreme provocations (active deterrence)
Type III—The deterrence of moderate provocations (tit for tat deterrence)

The requirements for the three kinds of deterrence, their interactions, some of the strains to which they might be subjected, and the probability and possible consequences of failure are discussed. Finally, criteria are set up for different circumstances and objectives to be used in the design and testing of the composition and posture of strategic forces. These are listed below:

Seven basic situations:
- A. Nontense:
    1. Premeditated Soviet attack
    2. Unpremeditated war
- B. Tense:
    1. Premeditated Soviet attack
    2. Unpremeditated war
    3. Premeditated U.S. attack
- C. Mobilization and legacy
- D. Arms control and violation

Attackers' objectives:
- A. Limit damage
    1. Counter force
    2. Postattack blackmail
    3. Civil and air defense
- B. in war
- C. in peace

Peacetime objectives:
- A. Type 1 deterrence
    - 1. Quality needed
    - 2. Second strike capability
    - 3. Attackers' defense
- B. Type 2 deterrence
    - 1. Necessity
    - 2. First strike capability
    - 3. Non-alert capability
- C. Not look or be too dangerous
    - 1. To us
    - 2. To allies
    - 3. To neutrals
    - 4. To enemy

Defenders' objectives:
- A. Punish enemy
    - 1. Priority affected by damage accepted
    - 2. Population and recuperation targets
- B. Stalemate war
    - 1. Conflicts with punish enemy
    - 2. Requires staying power
    - 3. Feasibility varies
- C. Limit damage

LECTURE III. WORLD WAR I THROUGH WORLD WAR VIII

Some characteristics of eight wars, real or hypothetical, are analyzed, partly to show relations between strategy, tactics, and technology; and partly to illustrate certain historical themes or possibilities. The eight wars, each a technological revolution ahead of its predecessor, are assumed to have occurred as follows: 1914, 1939, 1951, 1956, 1961, 1965, 1969, and 1973. The historical themes associated with each war are listed below:

1914—An accident prone world miscalculates. Expectations are shattered.

1939—Type II and type III deterrence fail. Expectations are shattered.

1951—A militarily superior nation risks disaster.

1956—Type II deterrence wanes.

1961—The Soviet Union attains "parity." Type II deterrence disappears. Type I deterrence is marginal.

1965—The prematureness of "Minimum deterrence."

1969—Possibility and consequences of "Minimum deterrence." Arms control or "?"

1973—Fourteen years of progress (or 50,000 buttons).

Senator **Anderson**. I think it has been a most interesting discussion. We will resume the afternoon session at 2 p.m., in this room, with testimony from Commissioner Willard F. Libby of the Atomic Energy Commission on emergency protection measures.

Following his testimony there will be a panel of the following individuals who will discuss the strategic implications of deterrence: Dr. Willard F. Libby, Comissioner, U.S. AEC; Mr. Robert Corsbie, Director of Civilian Effects Test Group, AEC; Dr. Paul Tompkins, NRDL; Mr. Herman Kahn; Mr. W. E. Strope, NRDL.

I hope you can be here at 2 o'clock.

Mr. **Kahn**. Thank you, sir.

(Whereupon, at 12:30 p.m., the hearing was recessed, to reconvene the same afternoon at 2 p.m.)

AFTERNOON SESSION

Chairman **Holifield**. The committee will be in order.

Just before the noon recess we heard from Mr. Herman Kahn, who testified in advance of his position on the agenda in order to accom-